NUCLEAR FISSION OF URANIUM

A DISSERTATION

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(65)

...........dedicated to my father.

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In compiling this bibliography, I have incurred many debts of gratitude. Firstly, I owe a deep debt of gratitude to my affectionate teacher Prof. M.H.Rizvi, Head of the Department and University Librarian for his keen interest in the compilation of this bibliography.

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SHAMIMUDDIN KHAN.

Aligarh

Dated :

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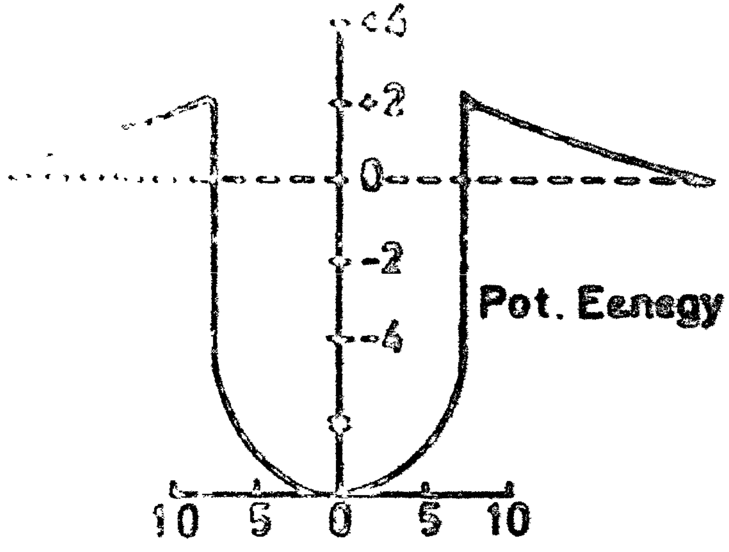
PART 1 INTRODUCTION

INTRODUCTION

J.J. Thomson's Model of the atom was the first systematic effort to explain the structure of an atom. On the basis of the x-ray scattering experiments with atoms, he pointed out in 1907 that the atom of an element consists of negatively charged electrons and positively charged particles in equal numbers which are uniformly distributed in the spherical volume of the atom whose radius is of the order of 10^{-8} cms. Soon after in 1911 Rutherford reported the results of -scattering experiments by atom of air, mica and gold in which he found that alpha particles were occasionally deflected from their path by large angles. These observed facts could not be explained by J.J.Thomson's x-ray scattering theory. Rutherford showed by a systematic theory of α -scattering that each atom has a small control nucleous which contains all the positive charge of the nucleus. The radius of this central region was shown to be less than 10^{-12} cms. The electrons of atoms occupy positions outside the nuclear volume. Thus the central nuclear region was 10^{4} times smaller in dimension than the atomic radius. Since the electrons are very light particles, most of the mass of the atom was concentrated in a small nuclear region in an atom.

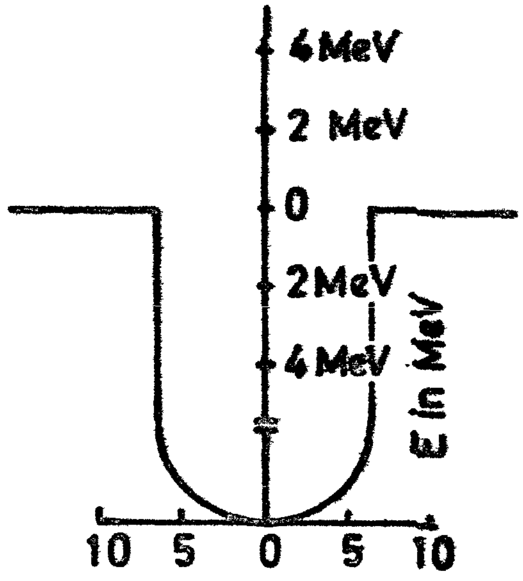
If one takes the nucleus of a heavy atom, the nucleus will be at rest during the scattering of an alpha particle which is relatively lighter as the centre of mass will still be inside the target nucleus. The energy of alpha-particle incident on the nucleus will be unaffected due to electrons in the periphery of the atom due the collision will be a purely elastic collission governed by coulomb's law of force between the positively charged nucleus and the incident alpha particles.

Nuclear masses are usually measured with good accuracy by the help of mass-spectrographs J.J. Thomson found that neon nucleus has two masses and one of them was about 10% heavier than the other. These were designated as Ne^{20} and Ne^{22}. With the help of modern mass spectrographs atomic masses are measured to six and seven significant figures and much useful information is derived figures and much u structure from each measurements. Masses are measured in comparison with oxygen isotope O^{16} which is supposed to have a mass of 16000,000 mass units. One mass unit in this manner is equal to 1.6599×10^{-24} grams. It is common practice to write masses in terms of m.u. or m.m.u (milli mass unit) The atomic mass measurements have recently been done in comparison with C^{12} isotopes taken as 12.0000, a.m.u. This results in the reduction of all previous masses on O^{16} scale by 0.0131.8%.



$r - 10^{-13}$ Cm

Potential energy with separation particles for protons.



Potential energy with separation particles for neutrons.

Nucleus are bound together in a nuclear potential well. Protons which are positively charge are, however, repelling one another by a coulomb's repulsive force. The nuclear potentials for protons and neutrons will, therefore, have slightly different from due to coulomb's repulsive potential acting for protons and no repulsive potential for neutrons which are electrically neutral. These potential can be shown as plotted in Fig. (a) and (b).

The coulombs potential energy for protons inside a nucleous is given by V(r) = 3/5 (Ze /r). Individual nucleous are bound inside the nuclear potential well in different stationary states so that their building energy is given by B.E. = Potential energy - K. E.

Constituents of Nuclei

Several theories were proposed about the nuclear constitution. Prominent among these is electron proton theory and proton neutron theory.

(1) Proton-electron hypothesis : Before discovery of neutron it was considered that the nuclear matter was consisting of protons and electrons. This concept arose because electrons were found to be emitted by radio-active nuclei in betadecay process. This concept seemed to be sound, as electrons were found to be emitted by beta active nuclei but several serious objections were raised against them.

(ii) <u>Proton Neutron hypothesis</u> : According to Proton Neutron theory which has been accepted these days, a nucleus consists of Z number of proton and N number of neutrons so that the nuclear mass number is given by $A = Z + N$. The number of electrons outside the nucleus is equal to Z, the number of protons while the neutrons are electrically neutral.

The electrons do not exist inside the nucleus but at the time of transition either a proton converts into a neutron and a positive electron ($p^+ \longrightarrow n + e^+$) or a neutron converts into a proton and a negative electron ($n \longrightarrow p^+ + e^-$) in radio-active transformation of the nucleus during β -decay.

<u>Classification of Nuclei</u> :

Different kinds of atoms of various elements are classified in three categories.

(i) Atoms which have the same Z number but different mass number A are called Isotopes. These isotopes although have the same chemical behaviour but are having different number of neutrons inside their nuclei.

(ii) Atoms which have the same number A but different Z are called isobars. These isobars possess different chemical and physical properties. In Isobars both Z and N bumber are different.

(iii) There are atoms which have the same Z number and the same mass number A but are different in their nuclear energy states. These nuclei are distinguished by their different life times, such nuclei are called isomeric nuclei or isomers.

<u>Nuclear Reations</u>

When a nucleon or a nuclear particle gets in a close contact with another nucleus, the in-cident particle and the target nucleus form a composit system which is in an excit excited state and after a short while a reaction is produced.[1] This phenomenon is called a nuclear reaction. Nuclear reactions are generally produced by exposing the nuclei of a target to a beam of nuclear projectiles or gamma rays.

If enough energy is given to nucleus by the incident particle, the excess excitation energy of the target nuclei can be released by the emission of a gamma ray, an alpha particle, a neutron, a proton, a deutron or multiple nucleons. A heavy nucleus might undergo fission by breaking into two heavy fragements. If the energy is large the nucleus might undergo disruption with emission of small fragments along with the emission of a few neutrons or protons. At energies above 135 Mev. new types of particles (i.e. π -mesons) are produced.

The first nuclear reaction was produced by Rutherford by alpha particles from natural radio-active sources. This reaction was studied in cloud chambers and was identified to proceed as,

$$N^{14} + \alpha \longrightarrow O^{17} + p \qquad \ldots (1)$$

The first reaction produced by an artificially accelerated proton was observed by Cockcroft and Walton and was identified as

$$Li^{7} + p \longrightarrow He^{4} + He^{4} \qquad \ldots (2)$$

Now-a-days, it has become a common practice in nuclear laboratories to produce nuclear transmutations of elements by suitable nuclear projectiles. There is an entire branch of science known as Radio Chemistry which deals with the production and study of artificially produced isotopes. These reactions can be produced by accelerated charged particles, neutrons and gamma rays. We shall examine the different aspects of nuclear reactions which are produced by those projectiles which transfer an energy to the target nuclei which is not much greater than the mean binding energy of single nucleons i.e. <50 Mev. In such reactions, meson production or complete disruption or spallation of nuclei does not take place.

In a nuclear reation, when a projectile 'a' comes in a close contact with a nucleus X, an exchange of energy and momentum takes place between the two particles, after a short time, one or more nuclear particles, or a gamma ray is emitted from the resulting interaction along with the product residual nucleus. The available energy is equitably shared by the emitted particle and the residual nucleus. A nuclear reaction can be written as :

$$a + X \longrightarrow y + b \qquad \ldots\ldots(3)$$

where 'a' is the incident particle, X is the target nucleus, Y is the residual product and b is the resulting particles a and b are the incident and outgoing particles respectively and these may be any of the following particles neutron proton, deutron, alphaparticle, gamma ray or a few nucleous. The nuclear reation of equation(3) is also written as

$$X\ (a,b)\ Y$$

In all these nuclear reation certain laws of conservation are obeyed. Some of the physical quantities which are conserved are as follows;

(a) Total charge before and after the reaction is conserved.

(b) Number of nucleous before and after the reaction is conserved.

(c) Total energy of the particles before and after the reactions remains the same.

(d) Linear momentum, angular momentum, isotonic spin and parity are the other physical quantities which are also conserved in a nuclear reaction.

Energetics of a nuclear reactions

Total energy in the case of nuclear reactions includes the rest energy because the mass and energy are interconvertable quantities inside the nucleus.[1] Due to this we generally express the enrgy as rest energy m_0C^2 plus the kinetic energy Ek in the energy balance equations of the nuclear reactions. In these notations the masses are generally expressed in energy units.

If the target nucleus is of energy Mx and a projectile of energy Ma + Ea impinges on it with the result, a product nucleus of energy $M_y + E_y$ and a particle of energy $M_b + E_b$ are formed, then on the basis of the conservation of energy, the nuclear reaction can be written as :

$$M_x + (Ma + Ea) = (M_y+E_y) + (M_b+E_b)$$

or $$(M_x+M_a) - (M_y+M_b) = E_y + E_b - E_a$$

If we write $\sum M_i = M_x + M_a$ and

$$\sum M_f = M_y + M_b$$

as initial and final rest mass energies and E_i and E_f as initial and final energies respectively, then

$$\sum M_i - \sum M_f = -(\sum E_i - \sum E_f)$$

and $$Q = \Delta M$$

$$Q = -\Delta E$$

where Q is called the reaction energy or Q-value of the nuclear reaction. The Q value of the nuclear reaction is a very important parameter and has a similar role at the Q-values in chemical reactions.

Compound Nucleus and Nuclear Reactions

The binding energy of nucleus inside the nucleus it was observed that the share of binding energy with $A > 20$ and the nuclear density remains practically constant. This property is similar to a drop of liquid where different particle are bound inside by molecular forces and are in random kinetic motion sharing energy from one another. Nucleons inside the nucleus also have a kinetic energy of about 20 Mev and are bound inside a nuclear potential well of 30-35 Mev. If a nuclear projectile from outside enters a nucleus with some kinetic energy, the other nucleons immediately share its energy and divide it randomly to all the nucleus present inside the nucleus. The excitation energy is therefore very quickly distributed among the constituent nucleus. The nucleus gets heated up just as a liquid drop is heated up after getting energy from outside. In this process of energy sharing, if a nucleus or a group of nucleus get an excess kinetic energy which is equal to or greater than their binding energy, these particle are released from the nuclear binding and become free. A resulting nuclear reaction can be written as

$$a + X \rightarrow C \rightarrow Y + b$$

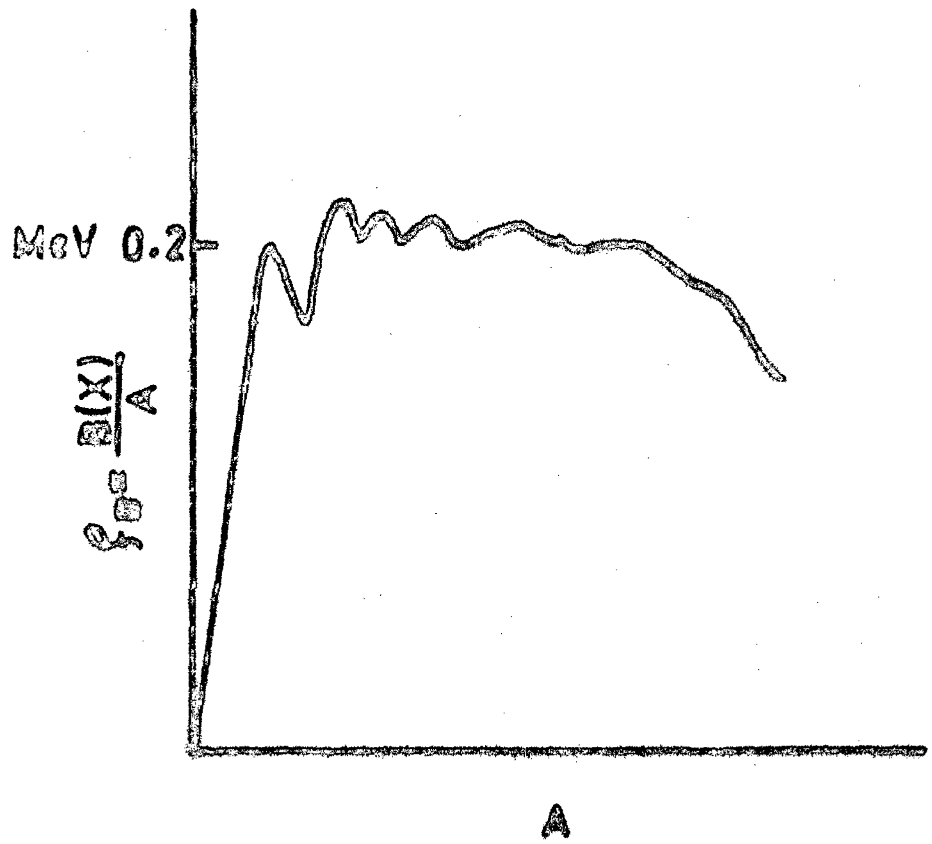
Where C is the compound nucleus.

This concept of formation of intermediate state and the emission of nuclear particles was first given by N.Bhor. This concept is helpful in explaining several important properties of low energy reactions. According Bohr the nuclear reactions take place in two stages. First the compound nuclear is formed and the excitation energy is randomly divided among the constituent nucle us. After a short while 10^{-15} sec to 10^{-7} sec one of the nucle us or a group nucle us collects a major share of the excitation energy is ejected out of the compound nucleus. In case the excitation energy is less than the binding energy of nucleon, the excess energy is given to a gamma ray photon which is limitted in due course.

The compound nucleus can be formed in different ways and can decay also through different channels. As an example we can take the formation and decay of ${}_{13}Al^{27}$ nucleus.

Formation — Decay

$$\left.\begin{array}{l} {}_{13}Al^{27} + r \\ {}_{13}Mg^{6} + {}_{1}H^{1} \\ {}_{12}Mg^{25} + {}_{1}H^{2} \\ {}_{11}Na^{13} + {}_{2}He^{4} \end{array}\right\} \longrightarrow {}_{13}Al^{27} \longrightarrow \left\{\begin{array}{l} {}_{13}Al^{27}_{3} + r \\ {}_{13}Al^{26} + {}_{o}n^{1} \\ {}_{12}Mg^{26} + {}_{1}H^{1} \\ {}_{12}Mg^{26} + {}_{1}H^{2} \\ {}_{11}Na^{23} + {}_{2}He^{4} \end{array}\right.$$



Binding energy diagram

Al^{27}_{13} here is the compound nucleus and is in an excited state. The excess energy of this nucleus is called excitation energy(E_c) The excitation energy can be estimated from the binding energy curve in the following manner :-

Binding energy diagram

We can write the rest mass energy of a nucleus as:

$$M_x = (ZM_p + NM_n - Af_B)$$

where f_B is the average binding energy per particle of the parent nucleus.

Similarly the rest mass energy of the compound nucleus will be written as :

$$M_c^{+} = (ZM_p + NM_n - A'f_B)$$

If the rest mass energy of the compound nucleus in its ground state considered just before its formation, then it will be

$$M_c = (ZM_p + NM_n - Af_B)$$

Hence the excitation energy will be

$E_c = (M_c^+ - MC) + E_a$

$= (A'fB - AfB) + Ea$ approximately

$= 8.2$ MeV $(A'-A) + E_a$ in the case of middle group

of nuclei. For slow neutron projectiles

$E_a = 0$

and $E_c = 8.2$ MeV $(A'-A)$

$= 8.2$ MeV approx as

$A' = A+1$

If α particles $({}_2H_c^4)$ are used to bombard targets

which have binding energy per particle

$\simeq 8$ MeV then

$E_c = (4x8 - 4x7)$ MeV $+ E_a$

$\simeq 4$ MeV $+ E_a$

and similarly if Deutrons $({}_1H^2)$ are used as projectiles,

then $E_c = (2x\ 8 - 2.2\ )$ MeV $+ Ea$

$\simeq 14$ MeV $+ Ea$

Protons used as projectile will give an excitation

energy $E_c \cong (1x8 - 0\ )$ MeV $+ Ea$

$= 8$ MeV $+ Ea$

In this manner we see that protons or neutros as well as alpha particle give an excitation energy to target nuclie which is either of the order of the binding energy of the individual nucle us or is lower. Hence in order to get a transmulation reaction in which a nucleon or a group of nucle us are produced after the disintegration of the compound nucleus, we have to give a large initial accelration to the projectile.

<u>Nuclear Transmultations produced by different Kinds of Projectiles</u>

In the early period of development of nuclear physics, nuclear reactions were studied by bombarding targets materials with alpha particles but with the invention of accelerating machines, other nuclear projectile like neutrons, protons, deutrons and also gamma rays were available to produce artificial transmulation of elements, with the present day machines, a wide energy range of particle as projectiles is available. Electrons are also accelerated to about 500 Mev energy which are used to produce very hard γ-rays some of the important transmulation reactions induced by different kinds of projectiles at low energy < 50 MeV are discussed in the following lines.

(a) Protons induced transmulations

The first artificial transmulation produced by artifically accelerated protons was due to cock-croft and Walton by 7MeV protons with Lithium nucleus.[1] The reation was detected in a cloud chamber.

$$_3Li^7 + p \rightarrow (_4Be^8) \rightarrow {_2He^4} + {_2H^4}$$

This reaction can be written as $Li^7 (p, \alpha)_2He^4$ other umportant example of (p, α) reactions can be written as

$$_3Li^6 + p \rightarrow (_3Be^{+7}) \rightarrow {_2He^3} + \alpha$$

$$_4Be^9 + p \rightarrow (_5Be^{10}) \rightarrow {_3Li^6} + \alpha$$

$$_9F^{19} + p \rightarrow (_{10}Ne^{+26}) \rightarrow {_8O^{16}} + \alpha$$

Protons can also produces (p,n), (p,d), (p,r) and (p,np) reactions. Some typical examples of such reactions are given below.

(p,n) reaction :

$$_5B^{11} + p \rightarrow (_6C^{+12}) \rightarrow {_6C^{11}} + {_0n^1}$$

$$_{28}Ni^{58} + p \rightarrow (_{27}Cu^{+59}) \rightarrow {_{27}Cu^{58}} + {_0n^1}$$

(p,d) reactions

$$_4Be^9 + p \longrightarrow (_5B^{+10}) \longrightarrow {_4Be^8} + d$$

$$_3Li^7 + p \longrightarrow (_4Be^{+8}) \longrightarrow {_3Li^6} + d$$

(p,r) reaction

In these reactions the daughter product is produced in its excited state by the absorption of a proton and comes to its ground state by the emission of a gamma ray photon.

$$_3Li^7 + p \longrightarrow (_4Be^{+8}) \longrightarrow {_4Be^8} + r$$

$$_6C^{12} + p \longrightarrow (_7N^{13})^+ \longrightarrow {_7N^{13}} + r$$

$$_9F^{19} + p \longrightarrow (_{10}Ne^{20})^+ \longrightarrow {_{10}Ne^{20}} + r$$

These reactions sometime give quite high energy photons asin the case of Li^7 which gives $\simeq$ 17 MeV gamma rays.

(b) <u>Transmulation produced by neutrons</u>

Neutrons have no electric charge and therefore can go inside a positively charged nucleus without over coming a repulsive force unlike protons, deutrons and alpha particle projectiles. Thus, even slow moving neutrons can be used for nuclear transmutations. Slow neutrons have a greater probability of producing nuclear reactions and they are generally showed down in paraffin or water before being used for transmutations.

(c) Deutron induced transmutations

Deutron give largest excitation energy to the compound nucleus and after neutrons, these particles are the best for nuclear transmutation.

(d) Photo disintegration reactions

Photo disintegration takes place if the gamma ray energy is enough to librate the nuclear particle from its binding inside the nucleus. Low energy gamma rays are able to produce photodisintegration of deuterium nucleus as the binding energy of deuterium is 2.225 MeV only.

$$_1H^2 + r \longrightarrow p + {}_0n^1$$

Nuclear Fission

Some of the heavy nuclides like uranium and Thorium break up into those heavy fragments with an extremely slow rate in the natural course of time. This phenomenon is technically known as autoffision and takes place with an average life time of $\simeq 10^{21}$ years in the case of uranium. Many heavy nuclei undergo fission by the bombardment of energetic neutrons, protons, deutrons, alpha rays and r-rays. The efficiency of these reactions is poor and fission yield is very small. These reactions are therefore of no practical importance. The slow neutron fission of uranium isotopes U^{233} and U^{235} and Pu^{239} are the only processes which are known to give high yields and are of a great practical importance.

The most important feature of the fission reaction is that each fission of the nucleus by an incident neutron produces more than one neutron when the fissible nucleus break up into two nuclear fragments. Out of the three istopes i.e. U^{238}, U^{235} and $\underset{U}{234}$, U^{235} isotopes alone is useful as it is fissible with thermal neutrons. The fission of U^{235} is expressed by the

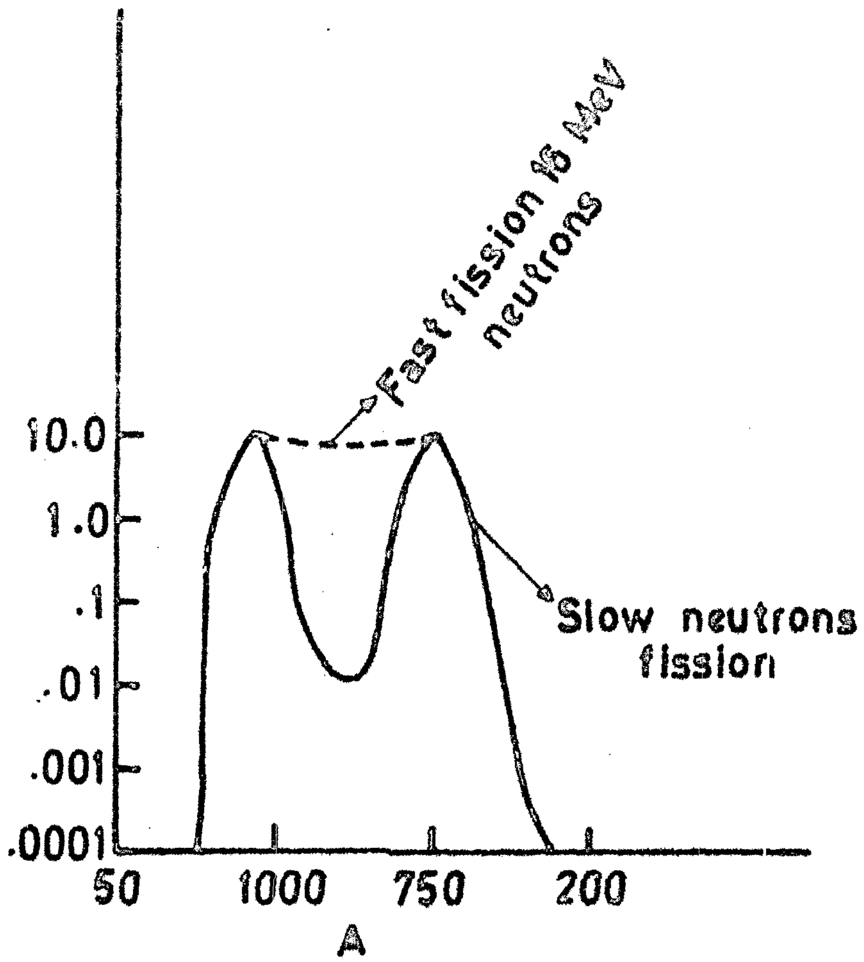
$$_{92}U^{235} + {}_{0}n^{1} \rightarrow U^{*236} \longrightarrow \quad X_1^{*} + X^{*}_2 + \bar{\nu}\ n' + Q$$

where X_1^{*} and X^{*}_2 are fission fragments of intermediate mass and is the average number of neutrons produced in every such fission. The Q value of the reaction is the form of the kinetic energy of fission fragments and neutrons.

The fission fragments when produced have a large excess of neutrons over protons and because they occupy a position some where in the middle group of nuclei in the periodic table. They are therefore, highly unstable due to a large neutron excess. These fragments limit r-rays, β particles and delayed neutron in quick transition in order to come to ground state. They release about 30-35 MeV of energy soon after their production. The final decay products which are formed, are not always the same but they depend upon the different decay claims through which they have been produced. Some of these decay chain have been systematically identified. One of these chains is indicated here as follows

$$
{}_0n^1 + {}_{92}U^{235} \longrightarrow U^{*236} \begin{cases} \longrightarrow {}_{40}Zr^{99} \xrightarrow{\bar{\beta}} {}_{43}Nb^{98} \xrightarrow{\bar{\beta}} {}_{42}Ma^{98} \\ \hfill + 2\,{}_0n \\ \longrightarrow {}_{52}Ti^{136} \xrightarrow{\bar{\beta}} {}_{53}I^{136} \xrightarrow{\bar{\beta}} {}_{54}Xe^{136} \end{cases}
$$

The fission yield consists of a large number of unstable and radioactive nuclides. Most of these fission products are -active and some give β and γ emission. When the excitation energy is large $\geq$ 8.5 MeV excess neutrons are also emitted by some fragments.



Distribution of fission yield with mass number A of fission fragments.

The relative abundances of final fission products have been analysed with the help of mass spectrometers and have also been estimated by chemical methods as well It has been established that the maximum yield of fission products is around mass number 96 and 138. This indicates that the nuclear fission is not symmetric. This characteristic asymonetry is slow neutron fission is found in U^{233} and PU^{239} fission as well. If, however, fission is produced by fast neutrons of energy $\geqslant$ 16 MeV, the nuclear fission becomes more and more symmetric. This fission yield of different fragments is shown in the fig.

The other two nuclei which under go fission by slow neutrons i.e. ${}_{92}U^{233}$ and ${}_{94}Pu^{239}$ do not occur in nature and are atificially produced in breeder reactors from ${}_{90}Th^{232}$ and ${}_{92}H^{238}$ by the following reactions.

$$ {}_0n^1 + {}_{90}Th^{232} \longrightarrow {}_{90}Th^{233} + \gamma $$

$$ {}_{90}Th^{233} \xrightarrow{\bar{\beta}} {}_{91}Pa^{233} \xrightarrow{\bar{\beta}} {}_{92}U^{233} $$

and $_{o}n' + _{92}U^{238} \longrightarrow _{90}U^{229} + r$

$$_{90}U^{229} \xrightarrow[\beta]{} _{93}Np^{239} \xrightarrow[\beta]{} _{94}Pu^{239}$$

Fission reaction of U^{238} and pu^{339} can be written as

$$_{92}U^{233} + _{o}n^{1} \longrightarrow _{92}U^{234} \longrightarrow \bar{X}_1' + \bar{X}_2' + \bar{r}' \; on' + \bar{Q}'$$

and

$$_{94}Pu^{239} + _{o}n^{1} \longrightarrow _{94}Pu^{240} \longrightarrow \bar{X}_1' + X_1'' + r'' + _{o}\bar{n}' + Q'$$

where the average neutron yoilds in these two reactions are given by r' and r'' and are 2.50 and 2.89 respectively.

Energy of Fission

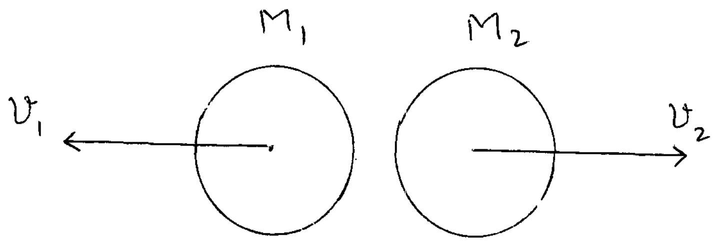
Energy produced in nuclear fission is extremely large as compared to the conventional sources. In every nucleus undergoing fission, a total energy of about 200 MeV is produced as kinetic energy. There are two ways by which you can estimate the energy of fission

(1) Estimation from the energy of fission

(2) Estimation from binding energy

Distribution of Energy of Fragments

The nucleus that is fissioned is normally at rest and the mass of neutrous produced in fission is very small as compared to the fission products. Therefore the two fragments carry nearly equal and opposite momentum.



(Fission fragments just after their formation)

$$M_1V_1 = M_2V_2 \quad \text{or}$$

$$V_1/V_2 = M_2/M_1$$

$$E_1/E_2 = \frac{\frac{1}{2} M_1 V_1^2}{\frac{1}{2} M_2 U_2^{\,2}}$$

$$= V_1/V_2$$

$$= M_2/M_1$$

Energy of fragments can be experimentally measured by a cloud chamber or a proportional counter.

<u>Neutrons released in Fission</u>

In each fission of a nuclear ν number of neutrons are produced on an average. Slow neutrons fission yields for U^{235} U^{232} and PU^{239} are all different.

These neutrons which are produced just after fission are admitted in the stages. Fission neutrons which are produced instantaneously constitute a majority of neutrons but a very small fraction $\leq .64\%$ of neutrons are emitted by the fission fragments in a time which ranges from a few seconds to minutes or so.

These neutrons are called the delayed neutrons. These delayed neutrons, although quite insignificant in number, held in controlling the fission reactions in nuclear devices like thermal reactors. There are several distinct groups of delayed neutrons with their own characteristic life time and decay rate. These rates and half lives are the property of the parent nuclear fragments which produce these delayed neutrons in a radio active decay process.

Energy released in Fission

To calculate the energy released in fission if a nucleus of mass number A and charge Z breaks into two smaller nuclei. In a simple case, let us assume that the two resulting nuclie are of the same size, then energy released can be calculated

$$E_f = \left\{ {}_Z M^A - 2 \left({}_Z M^{A/2} \right) \right\} c^2$$

Trans-Uranium Elements and their production

The elements occupying higher positions than $_{92}U^{238}$ in the periodic table are not found in nature as these are short lived w.r.to α-decay and also undergo an auto-fission. These are produced in the laboratory by various transmulation reactions. Transuranic elements produced by various transmutations are given as follows. Neptunium (Z = 93) Plutonium (Z = 94) Americium (Z=95), Curium (Z=96) etc.

These above elements are produced by the bombardment of the heavy nuclei by neutrons, particles, or either accelerated ions like carbon, boron or lithium, as shown in the following reactions

(1) Neptunium - $_{92}U^{238} + n \longrightarrow {}_{48}U^{239} \xrightarrow{\beta^-} {}_{93}Np^{239}$

(2) Plutonium - It is produced by the β decay of $_{43}Np^{237}$ nucleus as well as by an (α, n) reaction with $_{92}U^{238}$ nucleus.

(1) $_{93}Np^{239} \longrightarrow {}_{94}Pu^{239}$

(2) $_{92}U^{238} + \alpha \longrightarrow {}_{94}Pu^{241} + n$

(3) Americium - $_{94}PU^{241} \xrightarrow{\bar{\beta}} {}_{95}Am^{241}$

It decays by α - emission to $_{93}Np^{237}$

$$_{95}Am^{241} \longrightarrow {}_{93}Np^{237}$$

(4) Curium - It is 96^{th} element in the periodic table and is similar to rare earths. It was produced in the (α,n) reaction from $_{94}PU^{239}$ as follows

$$_{94}PU^{239} + \alpha \longrightarrow {}_{94}Cm^{242} + n$$

These elements are all unstable and have been produced through various nuclear reations.

In nuclear fission we either use uranium or Thorium because they are heavy elements. When there is fission of nucleus of those elements by bombarding the particles on the nucleus some neutrons evolve in the reaction. These neutrons again react with the nucleus and some more neutrons will evolve. So in this way these neutron which are evolving in the reaction will react with the nucleus and continously give the neutrons. So it is a chain reaction which will never end and more and more energy will produce in the reaction. It is easy to produce energy but the problem in how to control the energy.

PART II ANNOTATED LIST

ASYMMETRIC FISSION

1. KOLB (D) etc. Asymmetric fission of ^{236}U in a self a consistent K-matrix model. Phys.Rev.C. 10,4. 1974. 1529-47.p.

A simplified Brueckner-Hartree-Fock produce introduced by Meldner is expressed in terms of a semi-phenomenological single-particle K-matrix. Pairing and Centre-of-mass correction are included and bases consisting of the nonorthongal eigenstates of the shifted deformed axially symmetric harmonic oscillators are used with parameters obtained mainly from nuclear matter andclosed-shell nuclear properties Extensive results on nucleon density contours at points on the way to scission show the early presence of binary cluster structure as well as radial density fluctuations or bubble structure. Nucleon single particle levels and other nuclear properties are also calculated as a function of deformation along the fission path.

2. SLAVOV (B) etc. Asymmetric fission in the two centre shell. model Phys.Lelt.B. 37,5; Dec.,1971: 493-36.

A simple two center shell-model (TCS) is proposed for the description of aymmetry in the fission process.

Preliminary calculations so far have been performed for ^{210}Po, ^{136}U, ^{242}Cm and ^{254}Fm. It turn out that with the imposition of volume conservation in the simplest way possible the bare TCS model without inclusion of more sophisticated terms such as, pairing correction and energy renormalization, yields striklingly good results for the experimental mass ratios of the fission fragments.

ADYMMETRY-MASS

3. LICHTNER (P) etc Fission was asymmetry as a dynamic process. Proceedings of international conference on Nucl. Phys. Vol. 1 Germany 27 Aug.- Ist Sept. 1973 590 p.

From a two center shell model describe by the parameter distance between the two centres R; neck E; deformation of the two oscillators; and an asymmetry parameter = $(CA_1 - A_2)/A$, where A_1, A_2 are masses of the two fragments, collective potential energy surfaces and mass parameter have been calculated for ^{236}U and other nuclei. The collective Hamiltonian is solved in the extreme adiabatic limit assuming that the equations decouples leading to a one-dimensional equation in the asymmtry vairable.

ATOMS

4. BLOOM(SD), Difference in the eletronic and fission decay modes for muonic atoms.

Phys.Lett.B. 49B, 5; March,1974,420-2

A simple model is presented which predicts a difference in the electronic and fission decays of ground state munoic heavy atoms. It is interpretable in terms of the relative population of two nuclear states; the isomeric fission state and the groved state. The application of the model to ^{238}U indicates there could be a significant population of the isomeric state at the end of the mumnic atomic cascade.

AXIAL ASYMMETRY

5. SCHULTHEIS (H) and SCLTHEIS (R), One of the acial asymmotry of a fission nucleus. Proceedings on the international conference on Nuclear Physics Vol.1. Germany, 27 Aug-1 Sept 1973, 591 p.

The usual two spheroid scission configuration has been extended to tri-axial ellipsoids in order to study the behaviour of the potential energy under non-axial deformation of both fragments. In this isolated case one can vary length, mass asymmetry and axial asymmetry simultaneously while reating a degree of numerical simplicity. It is found for ^{236}U that the effect of non axial deformation on the potential energy strongly depends on the mass asymmetry of the nucleus.

6. SCHULTHEIS (H) and SCHULTHEIS (R) Axial asymmetry and mass asymmetry at the Scission point.
Nucl.Phys. A A 215, 2; Nov 12,1973; 329-48.
In order to study the influence of deviations from axial symmetry on the potential energy at scission. The usual two-spheroid scission configuration has been extended to tri-axial ellipsoids The adiabatic assumption has been avoided by adjusting all -values to experimental data. Numerical results are given for twenty mass division of ^{236}U.

COEFFICIENT - DISTRIBUTION

7. KEROULAS (P,De) etc. Distribution coefficients of U and plutonium in the system (UPu) C + $(UPu)_2C3$.
J.Nucl. Mater 44,1; 1972; 64-70.
As part of a research programme on mixed U, Pu carbide, which is a possible fuel for fast reactors, the authors examined by microprobe analyser the distribution of U and Pu between the phases (U,Pu) C and $(U,Pu)_2C3$. Two types of sampler were available, with Pu/(U + Pu) ratio of .20 and .50.

CRYSTALOGRAPHY

8. ANDERSEN (JU) etc. Fission life time measured by Crystal blocking of fragments from $^{238}U(nf)$ reactions. Nucl.Phys. A A241, 2.April, 1975. 317-31 p.

The life time of ^{239}U compound nuclei formed in $^{238}U(nf)$ reactions has been measured at three neutron energies by the Crystal blocking life time technique. The results are $\tau = 300 \pm 70$ as (1.7 MeV). $= 200 \pm 55$ as (2.3 MeV) and 100 as C3.6 MeV). For the two lower energies the axial and planar method for efective extraction have been compared and the results are in reasonable agreement. The life times are combined with measured values of the fission probability $P = T/P$ to obtained the partial width for fission, and for neutron emission Those are in turn compared with theoretical estimates.

9. DOPPLEREFFECT-MEASUREMENT

NADKARNI (D.M.), etc. Correlation between energies and angle of particles emitted in thermal neutron fission of ^{235}U Nucl.Phys. A. A196, 1; Nov.20,1972; 209-15.

The energy distribution and yields of the particles emitted in the thermal-neutron fission of ^{235}U were measured with the same detector system for the cases when the average angles between fragments and particles were 90°, 46°, 27° and 11°. The data were analysed by Monta Carlo method to take into account the effect of the finite size of the source and the version detected.

10. TILL(CE) and LEWIS (RA) Proceedings of a Conference on neutron cross section and technology Vols 1 & 2 Washington, 4-7 March 1968
Reactivity measurements in critical assemblies of the Doppler effect in fissile materials ideally measure a quantity of direct interest the difference between the fission and absorption components directly in the flux and adjoint spectra of interest. In practice however the Doppler effect can be obscured by the effect of thermal expansion of the material.

ELECTRODEPOSIT-SOURCE

11. HASHIMOTO(T) Ejection of atoms from surface of electro-deposited U source by decay or fission reaction. Annu. Rep.Res.React.Inst.Kyoto Univ(Japan)6; 1973,10-17p.
The atoms ejected in vacuo from the surface of some thinly electro deposited U sources, such as U^{233},enriched(90%) and natural U, by -decay or fission reaction processes were determined.

ELECTRO FISSION

12. REIDCJMI and HNDRY (Jn) The electrofission of ^{238}U. Proceedings of the International Conference on Nucl. Phys. Vol. 1 Germany 27 Aug-1 Sept, 1973; 602 p. A beam of electrons of 70 MeV was used. The energies of fragments emitted from the reaction have been measured with surface barrier detectors to an accuracy of 1 MeV notwithstanding the radiation back-ground. This has been made possible by careful consideration of the back-ground and the development of special configuration detectors.

ELECTRON

13. KHAN (TA) etc Prompt electrons from neutron induced fission of U-235, J. Phys. 33, 8-9, August-Sept, 1972; 30 (European conference on nuclear physics Abstracts only Aix-en-Provence, France) 26 June-1 July 1972. The spectra were obtained with enough resolution to determine approximate K/L ratios wherever possible and so assign multipolarities to the observed transitions. By comparing the electron line energy with that of the corresponding gamma-ray tentative assignment of the charge of the fragment giving rise to the radiation was possible.

ELECTRON – BOMBARDMENT

14. REID (J.M.) etc. Electro-fission below 100 MeV electron energy J.Phys. 33, 8-9; Aug-Sept. 1972; 27 (European conference on nuclear physics. Abstracts only, Aix-en-Provence, France 26 June-1 July 1972)

The energies of prompt fission fragment from natural uranium has been measured using solid state countries for various electron bombardment energies between 30 MeV and 100 MeV. The problem of r flash has been reduced to a minimum vy careful arrangement of counters and electronics. A preliminary analysis of the data indicates that the energy spectra depend upon the incident electron energy.

ENERGY – CONVERSION

15. DYACHENKO (P.P) etc. Energy dependence of yields and kinetic energies of ^{235}U fission fragments. Yadernaya Fiz 14,6; 1971· 1129-33 In Russion English Translation in :Sov J.Nucl.Phys. (USA)

Results are presebted for the energy and mass distributions of fragments in the U^{235} fission by monoenergetic neutrons within 0.6 $\div$ 3 MeV with the step 100 $\div$ 250 KeV The results obtained confirm the presence of proviously found irregularities in the energy dependence of yields and kinetic energies of fragments in the neutron energy region En L 2.0 MeV. The effects observed are discussed in the frame work of existing models.

ENERGY - CONVERSION

16. FORELBERG (B) Evidence for a $J = 0^+$ first excited state of ^{98}Zr through a measurement of internal conversion electrons from fission products. Phs.Lett.B. 37 b,4; Dec., 1971; 372-4.
An investigation of conversion electrons from fission fragments and fission products of the ^{235}U (n,f) reaction has revealed a strong E0 transition in some isotope at Z = 40. Strong evidence that this transition depopulates the first excited state of ^{98}Zr is presented.

ENERGY - DISTRIBUTION

17. AHUJA (N) etc. Energy distrib of fragments from fission of ^{238}U induced by monoenergetic neutrons from 1.5 to 18.2 MeV (Lett.Nuovocimento) 3,4 Jan,1972 147-50.
In order to improve the experimental data on the dependence of the average K. of ^{238}U fragment as a function of neutron energy the fragment energy distribution was measured. The measurements were performed using mono-energetic neutron with 1.5, 5.2 and 18.2 MeV energies obtained by means of (d,n) reaction.

ENERGY - FRAGMENT

18. NASYROV (F) etc. Specific ionization distribution along track as a function of initial energy of U^{235} fission fragments. Atmonaya Energiya V 19,3; 1965 244-52 p.

The distribution of the specific ionization energy losses along the tracks of fission fragments was investigated as a function of the initial energy using a telescope comprising 11 ionization chambers in conjunction with a two dimensional pulse-height analyser. The fragments of U^{235} fission induced by thermal neutrons were investigated for the initial energies of the fragments ranging from 78 to 115.5 MEV for the light fragments and from 34 to 88 MeV for the heavy fragments. The dependence of the specific ionization energy losses of the fission fragments upon their velocity was determined showing somewhat different behaviour for the light and for the heavy fragments.

19. ENERGY - KINETIC DISTRIBUTION

PARKASH, (S) etc. Kinetic energy distribution in the thermal neutron fission of ^{233}U and ^{239}Pu. J. Inorg. and Nucl. Chem. 34,9; 1972; 2685-97

Recoil ranges of fission products in the thermal neutron fission of ^{235}U and ^{239}Pu were determined using radio chemical techniques as well as direct counting with a Ge(Li) detector. The recoil ranges were converted into kinetic energies using different range-energy equation and the relative merits of these equations are discussed. The K. deficit was calculated from the K distribution. From K distib the average K was calculated using the mass-yield data available in the literature. The average K- was found to vary linearly with the fissionability parameter. Deformation of fission fragments and the variation of the deformation as a function of fragment mass were calculated using the K- data.

20\. ENERGY-NEUTRON STATISTICAL
See
NEUTRON STATISTICAL-ENERGY

GARRISON, (J.D.) A method for the statistical analysis of the cross section of fissible nuclei conference on Nuclear structure study with Neutrons, Hungary, 31 Jul-5 Aug 1972. 206-7. A method for statistical analysis of the low energy neutron cross-sections of fissible nuclei has been developed which yield the mean total resouance width-T and the mean resouance spacing D. The results for ^{235}U are D = 0.38 ± .05 and T/D = .16 ± Approximately 50% of the resouances are not observed.

ENERGY-POTENTIAL
SEE
POTENTIAL-ENERGY

71. YAMAJI (S) etc. Total energy surface for ^{236}U in the two center shelcmodel. Proceeding of international conference on Nucl. Phys. Vol.1. Germany 27 Aug-I Sept 1973 596 p.

72. The total energy surface for ^{236}U was calculated in the frame work of the symmetric two-center model. The energy surface is expressed as a function of the deformation of each fragment and the center separation Zo. The nuclear radius parameter and the oscillator parameter were taken to be 1.2 fm and $41A^{-1/3}$ respectively.

ENERGY SEPARATION-TECHNIQUE

23. FLEURY(A) etc. Techniques of separation of $^{134}C_3$ isomers formed in fission of ^{238}U by particles of medium energy. Int.J.Plass spectrum. Ion Phys. 7,3, Sept. 1971, 221-5. The ratio of 134Cs isomers produced in the fission of ^{238}U by particles of energies 40-130 MeV who measured Two exat technique were used to separate to ^{134}Cs from the other fission products: a physical methods by means of an electromagnetic mass and a radio chemicals method. The two methods are compared. Their results are coherent and the isomer ratio is found not vary with bombarding energy.

FISSION

23. ADMOV(VM) etc. Long range fission particles. Soviet J.Nuclear Phys. 9,4; 1969: 732-9. Ratios of the decay probability of the fission with the emission of long-range particles of Th^{232}, U^{233}, Np^{237} by 14 MeV neutrons to the probability of the LRP fission of U^{235} by slow neutrons are determined. Yields of protons and tritons at the fission of the above nuclei by 14 MeV neutrons as well as at the fission of U^{233} by slow neutrons and at spontaneous fission of Cm^{244} are measured. In all cases spectra of particles and triton were measured. Proton spectra were measured at the fission of U^{235} by slow neutrons and the spontaneous fission of Cm^{244}. Coincidences between a fragment and a long range particle were registered.

24. CHRISTIANSEN(J) etc. Inventory of delayed fission in ^{236}U. Nuclear Phys. A. 239,2 Feb 1975. 253-9 P.

The fission isomer of 236U was produced by the reaction $^{235}U(d,p)$ ^{236}U using pulsed beam technique The half life of the fission isomer was determined to be $T_{1}/2 = 116 \pm 7$ ns An isomettic to prompt fission ratio /B = $(1.24 \pm 0.06) \times 10^{-5}$ was obtained. The measurements were performed with parallel plates avalanche detectors which proved to be a high efficiency low background system.

25. FELVINCI (J.P.) and MELKONIAN(E), Pulse-height effects in the measurement of ^{233}U fission cross section. <u>Trans Am.Nucl.Soc.</u> 19; Oct. 1974 402 P It is demonstrated that the fission cross sections are sensitive to pulse height bias and that level parameters calculated from biased measurements may be in error.

26. FURSOV (DI)etc. Measurement of the U^{238} and U fission cross section ratios at neutron energies ranging from 1.4 - 7.4 MeV. Neitronnaya fizika (Conference on Neutron Phys), Pt.IV Kiev USSR 28 May - 1 June 1973 3-12 P Measurement of the fission cross section ratio of B^{238} and U^{235} were carried out in the 1.4 to 7.4 MeV region using double ionization chamber. Neutron were produces by the use of a via de Great generator. T(p.m)He^3 and D(d,n) He^3 reaction were employed. The total uncertainity is about 2.5%.

27. ISLAM(MM) and KNITTER(HH) The energy spectrum of prompt neutrons from the fission of ^{235}U by 0.40 MeV neutrons. <u>NuclSci & Eng.</u> 50,2; Feb,1973; 108-14 The prompt fission neutron energy spectrum of ^{235}U was measured at an incident neutron energy of .04 MeV with

two samples of different thickness. The data were corrected for flux attention in the sample metrial and for effect due to the energy change of the out-going fission neutrons by inelastic scattering and secondry fission processes. After applying these shape correction, an average fission neutron energy of 2.06 ± 0.05 MeV was obtained using the walt and the Maxwellian funetri for the energy distribution of the fission neutrons. This result has been compared with the presently available results ofother work.

28. KARAMYAN(SA) etc. Energetic balance for nuclear fission with heavyions Sov. J. Nucl. Phys. 15,3,1972; 435-43.

The values of -number were measured for reaction of U^{238}, Bi^{209}, A_n^{197} nuclei with accelerated ions C^{12}, O^{16}, Ne^{22} and Ar^{40}. Using published data on the K and mass distributions of the fission products the total energetic balance of the above reaction were calculated. The eloborated method of energy balance calculation can be used in the calculation of number of fission reaction for which there no expt. data. The energetic balance of the hypothetic spontaneous nuclei fission is considered for Z 90. It is found that spontaneous ofission mechanism for ZC 84 nuclei should considerably differ from the usual one.

29. KULCINSKI (GL) etc. Fission gas induced swelling in urnaium at high temperatures and pressure. *J. Nuclear Materials*, 30,3, 1969, 303-13 p.
The effect of externally applied hydrostatic pressures from 0-1000 bar at 900°C on the gas fission induced swelling in urnaium has been studied. The swelling is a sensitive to pressures above 110 bar. Metallography of the samples show that the average diameter of the bubble is reduced from 3300 to 1800 A and the total number increased from 0.9 to 4.2 x $10^{12}/cm^3$ as the annealing pressure is increased from 0-110 bar respectively.

30. OGANESYAN(YU Ts) etc Determination of the reaction thresholds at bombardment of the nuclei ^{208}Pb and ^{238}U by the ions ^{40}Ar and ^{50}Cr *yed.Fiz* 21,2. 1975, 229-48P.
Production cross section were studied for the fission payments on thin targets of ^{208}Pb and ^{228}U, depending on the energy of the bombarding ions ^{40}Ar and ^{51}Cr In the case of the reaction ^{238}U + ^{40}Ar the energy dependance were also studied for production yields in the reaction with transfer of several nucleous. Using the results, the colum barrier of the interacting nuklei was determined as well as the corresponding effective interaction range which was found to be a constant 1.44 ± 0.04 for all the reactions. The data are compared with result of various calculations.

31. THEOBALD (J.P) etc. Fission components in ^{236}U neutron resouance.

Nucl. Phys. A. a 181, ?; Feb. 1972; 639-44.

Fission widths of ^{236}U neutron resouance have been determined in the energy range between 5.45 and 415 ev. They show small variations in this range and have an average of (= 0.35 mev. consequences of these results on fission barrier parameters of ^{237}U are discussed.

FISSION-ABSORPTION

32. BOUCHARD (I) etc. Measurements of integral cross-sesion of heavy isotopes by irradiation in fast neutron spectra. Conference on chemical nuclear data. Canterbury, England 20-22 Sep. 197.323-3p.

Presents results on   ratios of the absorption to fission rate of U^{239}, Pu^{239}, Pu^{240} and Pu^{247} and also on the absorption cross section of Am^{241} The accuracy obtained on these ratios is of order of 5% It is better than the accuracy obtained is other integral experiments and is quite sufficient for calculation adjustments.

FISSION-APPARATUS

33. RALAROSY (I) etc Use of plastic visual detectors for the study of the fission induced by heavy ions.

C.R. Acad Sco. B 269, 13; 1969; 593-6.

33. After a brief account of the technique and description of theapparatus used, the authors present several results concerning the fission cross sections of Uranium, thorium, bismuth and gold, induced by ^{22}Ne at 170 MeV. The value found are of the order of 1.3 barns. Two cases of triple fission have been analysed. The approximate masses of the fragments are given.

FISSION-BINARY
SEE
BINARY-FISSION

34. BACHMANN (K) and CUMMING (J.B) Fission of ^{238}U by 2.2 GeV proton II Phys. Rev C[U] 5,1; Jan. 1972; 210-19. Differential range covers have been obtained by radio-chemical methods for 17 isotopes of Cu, Sr, Pd and Ba which recoil out of thin U targets to radiated with 2.2 GeV proton. Neutron-rich isotopes of Ba, Pd and Sr all have sharply peaked spectra with mean momentum 120 consistent with their production by binary fission. Neutron difficient isotopes of these elements are characterised by lower mean momenta and broader spectra which include significant low-momentum components.

35. BHARGAVA (V.K.) etc. Studies of high asymmetric binary fission: fission of uranium with reactor neutron. Nucl. Phys. & solid stabphys. symposium abst only BARC.Feb 1972. 1

Preliminary results of work designed to define precisely the nature of the mass distribution in the highly asymmetric binary fission of heavy elements are presented from a radio-chemical investigation of the reaction neutron induced fission of natural uranium. The cumulative fission yield of five nuclide. Viz ^{66}Ni ^{67}Cu and ^{172}Er, ^{175}Yb and ^{177}Lu were measured relative to 90 Mo using stringent radio chemical separation procedures.

36. CHANG (S.K.) etc Recoil properties of Ta isotopes produced in the interaction of high energy protons with Bi and U : Phys. Rev. C. 10,6; Dec, 1974; 2467-71p.
Fission and spallation reaction were induced in ^{209}Bi and ^{238}U by bombardment with proton at 0.45 GEV and 11.5 Gev As a result of thick target thick catcher recoil measurements on the neutron deficient isotopes $^{172-179}Ta$ among the reaction products, it was infered the binary fission predoimates in the 0.45 GeV reaction while both fission and spallation are significantly represented in the 11.5 GeV reaction. A value of 588 ± 10 days was obtained for the half life of ^{179}Ta, from measurements on two samples over a year period.

37. KATCOFF (S) and HUDIS (J) Fission of L,Bi,Au and Ag induced by 29GeV 14 Nious Phys.Res.Let. 28,16; April, 1972; 1066-8.
The binary fission cross-sections measured with mica track

detector are threefold larger than with protons of 29 GeV. Ternary events are 1% of binary. With U, Bi and Au there is little preference emission of fragments into the forward hemisphere. There is no indication of introductions which involved large momentum transfers to heavy nuclei from 29 GeV ^{14}N ions. However, with Ag. targets there is evidence of significant momentum transfer.

38. RAHIMI, (F)etc Fission of U, Th, Bi, Pb and Au induced by 2.1-GeV ^{2}H ions. Phys.Rev.C. 8, 4; Oct. 1973; 1500-3. Binary and ternary fission cross-sections were measured with plastic detectors. For U and Pb the former were respectively 20 and 30% higher than for proton induced fission and the latter large by factor of 2 and 3, respect cross section are shown as functions of Ed and Z/A for the target and empirical correlations are suggested.

39. VATER (P) etc Fission studies in mica using the hole detecton (Proceedings of the 8th international conference on Nuclear photography and solid state Track Detectors. Vol. II Bucharest, Rumania, 10-15 July, 1972; 90-102.

The ratio of the ternary fission to binary fission in the interaction of U with 414 MeV Ar-ions was found to be

(2.4 ± 1.0%)%. Thin value was obtained using the hole detector technique, as suggested by starke. Some angular distribution of the fission fragments were also measured. The method was tested with natural U irradiated with thermal neutron.

40. WAGEMANS (C) and DERUYTTER (A.J.) Ratio of the ternary (LRA) to binary fission cross-section for ^{235}U in the resouance region (below 40 ev).
J.Phy. 33, 8-9; Aug-Sep, 1972; 19 (European conference on nuclear physics. Abstract only, Aix-en-Provence, France, 26 June - 1 July 1972).
Precise measurements were performed of the ratio of ternary to binary fission T/B for ^{235}U in the neutron energy region below 40 eV (by ternary fission is meant fission in two heavy fragments and one light charged particle, usually a long-range -particle or LRA). From the well-resolved time of flight vs neutron energy spectra recorded in both conditions, the ratios of the areas in the ternary and the binary spectra were calculated for the strongest isolated resouances.

FISSION-DATA ANALYSIS

41. AVLETSHIN (A.N) and TOLSTIKOV (V.A.) Programs for Processing neutron cross section experimental data.

Neitronnaya Fizika (Allunion conference on Neutron Phys.) Pl. 1, Kiev USSR, 28 May-1 June 1973, 252-7 P.
The paper presents brief information on a developed program for experimental data approximation by the orthogonal polynomial method. The application of the program to the evaluation of the ratio of ^{238}U radiative capture cross section to the ^{235}U fission cross section is considered.

42. BORISOV (G.A.) and VASILEV (R.D.) Estimating experimental fission cross-section for ^{238}U, ^{237}Np and ^{233}Th by neutrons of energies from threshold to 20 MeV. Neitronnaya Fizika (Conference) USSR 28 May - 2 June 1973 p.227-32.
In order to determine cross-section uncertain to the experimental data on ^{235}U, ^{238}U, Np and ^{232} Th fission cross section have been analysed. An attempt has been made to make the data of different authors in the energy region from a threshold upto 20 MeV agree, and to produce values of the cross-section and their uncertaintie.

43. FISSION-DISTRIBUTION

ANTANASIJEVIC (R) etc. The fission of Ur and thorium induced by 700 MeV/C K^- mesons. Fizikia 6, Supp, Dec 1974, 23 P.
In the experiment the fission of U and Th induced by Kesons of a moment of 700 MeV/C was investigated using ploy carbonate detectors. The basic characteristic of the fission of U and Th are given, and the massdistribution of fission fragments are determined.

FISSION-DISTRIBUTION

44. CARUANA (J) The angular distribution of fission fragment 4th AINSE nuclear physics conference. Abstracts of paper presented sydney, Australia, 14-17 Feb 1972. p.59

The main objective in observing fission fragments angular distrib is to improve existing theory on the final stages of the fission process. I, M and K which the parent nucleus had at the saddle point. Then from observed flight directions one can determine the saddle point transition states of the fissioning nucleus. In this study, the fragments from U 235 were observed at six angles relative to the incident neutron beam. The neutron energy ranged from thermal to 800 KeV and were produced by the proton bombardment of a lithium target. Gold silion surface-barrier detector were used to measure the fragment counts. Because low energy neutron have small angular momentum, they are very useful in studing the γ-spectrum of heavy nuclei. However better accuracies then existing today are needed to bring out the fine structure. The study of angular anisotropy permits the evaliation of K_o^2 an important parameter in the physics of fission.

45. DIKSIC(M) etc. Nuclear charge dispersion in mass claims 130-135 from the fission of ^{238}U by medium-energy protons. J. Inorg & Nucl. chem. 36;1;Jan, 1974; 7-16.

Independent formation cross sections of ^{131} Te, ^{131g}Te ^{130}I, ^{131}I, ^{132}I, ^{133}I, ^{134}I and ^{132}Cs and cumulative formation cross-sections of ^{131}Sb, ^{135}I resulting from the fission of ^{238}U induced by protons of 30-85 MeV energy have been measured.

46. KUIKEN (R) etc Fission of aligned ^{233}U nuclei by neutrons from 4 to 2000 eV Nucl. Phys. A a 190,2; 1972; 401-19.

The anistropy in the angular distribution of fission fragments from neutron induced fission of aligned ^{233}U has been measured as a function of neutron energy from 4 to 2000 eV. The variation in the anistropy over the resouances in the energy region from 4 to 60 eV and also over the unresolved region from 60 to 2000 eV was found to be rather small comparing the experimental distribution of anistropy values with theoretical distribution showed, that for the J = 3 resouances, channels with K = 3 are not open; K being the projection of the compound spin J on the deformation axis.

47. MARUHN (J) and GREINER(W) Theory of fission mass distribution demonstrated for ^{226}Ra, ^{236}U, ^{258}Fm. Phys.Rev.Lett. 32, 10, 11 March, 1974. 548-51.
Using the asymmetric two-centre shell model 3D minimisations of the necking parameter and fragmentation deformations for pairs of values of elongation and mass asymmetry were performed for single, double and triple humped mass distribution. The semiquantitative agreement with observation supports the model of mass yield distribution as determined by collective vibrations occuring during descent of the coulomb curve.

48. NGO(C) etc Search for Coulomb fission induced by 84Kr ions on ^{238}U Nucl.Phys. A. A 221, 1, 11 March, 1974, 37-44.
The authors have searched for coulomb fission induded by ^{84}Kr ion on a ^{238}U target at energies ranging from the interaction barrier down to 37 MeV below (408 - 458 Mev) No event attributed to coulomb fission was detected, it was deduced that the cross section for this reaction is lower than .3 mb/Sr near the interaction barrier. This value was compared to theoretical predictions. However, fission events originating from transfer reactions at the interactions barrier have been detected.

49. POSTMA(H) (n,r) reactions with the neutron-induced fission of oriented nuclei. Proceedings of 2nd international Conference on Polarized targets, Berkeley. 30 Aug-2 Sept 1977 237-46

50. The first type of experiment conern remission after capture of either unpolarized or polarized neutron by oriented nuclei. In the other experiments the directional distribution of fission fragments from aligned ^{233}U, ^{235}U and 237Np nuclei is studied. The latter give information about the nature of barrier states of highly deformed nuclei.

50. VIOLA (VE) etc. Linear momentum transfer in reaction between 140 MeV ^{4}He ions and heavy nuclei. Phys. Rev. C. 10,6. Dec., 1974.2416-24 p. The following fission reaction were studied by bombarding the appropriate targets with a 140 MeV beam of ^{4}He ions, from the Uni of Maryland Cyclotron: ^{238}U(d ,f) $^{2.9}Bi$(P) and ^{107}Sn (d,f) Fission cross sections and fragment fragment angular correlation were measured, and from these measurements linear momentum transfer distribution deduced. It is found that at the bomarding energy of 140 MeV less than half the total reaction cross section involves complete fission of

projectile and target, and that a large proportion of the incoming fusion events involves linear momentum transfers with 50-90% of the value associated with formation of compound nucleus. Possible extrapolution to lower bombardment energies is briefly discussed.

FISSION-ESTIMATION

51. KOSHIKIMA(T) Estimation of fission cross-section and range of fission fragment by means of track registration J.Nucl.Sci.& Thechnol. (Japan) 10,8; Aug. 1973 511-12.
They developed the etching technique for the visulization of fission fragment tracks, track registration has been increasingly applied to neutron detection and other uses. The author presents observation upon the range of fission fragment penetration inuranylacetate measured by method of track registration, and estimate of the effective fission cross-section of natural U for neutrons from a Ra-Be source.

52. AIELLO, V.MARACCI, G AND RUSTICHELLI,F. Transmission of ^{235}U fission fragments in solid meid.a Phys.Rev.B. 4,11,Dec. 1971; 3812-19.

Transmission measurements of the fission fragments arising in ^{235}U therma-neutron induced fission were performed in Au,Al,Pb and Ag by using a back-to-back fission chamber. From the transmission curves, it is possible to derive the relativistic atomic stopping powers of the different targets and the ranges of the fission fragments in the elements investigated. The experimental results are compared with theoretical calculations of Lindhard, Scharff, and Schiott concerning the loss of energy of heavy ions in matter.

53. ABEGG(R) etc. Fission fragments anistropy in ^{238}U (n,2nf) Helv.Phys.Acta, 46,4; 1 Dec, 1973; 445. (Swiss Physical Society Meeting Switzerland, 4-5 May 1973).

The aim of the study was to determine the fragment anistropy in the fission of ^{238}U by neutrons in the energy range 13 to 18 MeV Anistropy increased from .37 ± 0.06 at 13.7 MeV to .61 ± .07 at 14.0 MeV. The fragment angular distributions were measured by means of glass detectors.

FISSION,FRAGMENT-DISTRIBUTION

54. LOVELAND (WD) and SHUM(YS) Fission fragment angular momentum in charge particle induced fission. 1. ^{134}Cs and ^{115}Cd isomer ratios. Phys.Rev.C. 4,6; Dec,197; 2281-8. The ^{134}Cs and ^{115}Cd isomer ratios have been measured.

55. OGANESYTAN (YUTS) etc Mass and charge distrib of fission fragment in reaction with accelerated ions Xe and Kr. Sov. J. Nucl. Phys. 19,2; 1974;245-51. Mass and charge distribution of the fission products from nuclei Ta and U exposed to the ions of Kr and Xe measured. It is show that dispersion of these distribs, as well as peculiarities of formation of the fragments, differ only slightly from those expectedassuming the fission of a compound nucleus or a system produced at interaction of two composite nuclei.

56. RUBCHENYA (VA) Equilibrium-deformation and deformability of nuclei fragment IzV Akad Nank SSSR Ser. Fiz. In Russian 36,1; 1972; 212-4

English translation in : Bull Acad. Sci. USSR Phys. Ser. (USA)

The equilibrium-deformation of nuclei is established by finding the maximum of the binding energy with respect to the quadrupole deformation parameter. Values of this parameter are given for the most probable even-even nuclei-fragments, from the division of ^{235}U by neutrons. as a function of the mass number. In addition to the known range of deformed nuclei of the rare-earth elements the nuclei with A 90 to 110 are also deformed.

FISSION-GAS

57. BAINBRIDGE (JE) and HUDSON(B) On the techniques for observing fission gas bubbles in Uranium. J. Nuclear Materials. V 17, 3, 1965, 237-44 P. Replicas taken from Cathodically vacuum etched and fractured surfaces have been compared with the results from thin film electron microscopy to determine the limitation of each technique. Cathodic etching enlarges bubbles 150 A diameter by a factor of 2; only cleavage surfaces from the fracture produce results comparable with the bubble size distributions obtained by using other technique. With bubbles 500 A the thin film techniques is no longer reliable. The results give an experimental value for the surface energy of -Uranium of 1000 erg/cm^2.

FISSION, GASEOUS-APPARATUS

58. CARROLL(RM) etc. Fission density, burning, and temperature effects on fission gas release from UO_2. Nuclear Sci. Engng. 38,2, 1969, 143-55. Two cylindrical specimens of UO_2 were irradiated in Oak Ridge Research Reactor at temperature upto 1700^{o}C. Both specimensuere of neutral enrichment U but one specimen was a single crystal and the other had a fine-grain microstructure. The fission gas release from these specimens were effected by the fission density, temperature burnup, grain growth, and the

cracking of the specimen. Concentration of fission gas produced high local stresses which contributed to the cracking of the specimen.

59. KALIMA (J) etc. Apparatus for studying gaseous fission products released from irradiated ceramel material Jad.Energ. 20, 7; July 1974. 224-9P.
Apparatus for the study of release kinetrics fission product from irradiated uranium dioxide is described In the design of apparatus, the exact temperature measurement, and regulation and possibility of Kr and Xe separation have been emphasized, along with the purity of the protecting atmosphere around the sample. The aclibiration of the equipment and the experience obtained in measurements of the release kinetics is described.

FISSION-GOLD

60. RALAROSY (J) etc. Fission cross section of U, Th, bismuth, lead and gold induced by 59 to 100 MeV particles. Phys.Rev.C.8,6. Dec 1973;2372-8.
The experimental technique using a makrofoil detector is described. Measured cross sections are compared to other experimental data and to theorial predictions. Their energy avatiation as a proportion of the total reaction cross section calculated from optical model is discussed.

FISSION-ISOMERS

61. TSUKIHASHI (Y) and TAKEUCHI(E) Search for fissioning isomers of ^{237}U and ^{236}Np by using 14.8 MeV pulse neutron. Bull Inst.Chem.Res. 52, 1. Jan 1974. 137-41 p.

Search for fissioning isomers of ^{237}U and ^{236}Np was made by using the $^{238}U(n,2n)$ and ^{237}U and reactions with 14.8 MeV pulse neutron in the region of the half-lives over 60 s. The upper limit of delayed/ prompt values were obtained to be about 1×10^{-6} for both ^{237}U and ^{236}Np fissioning isomers with the region of half lives studied.

FISSION -MEASUREMENT

62. ALELIO(U) etc. Single rod fine distribution of the fast fission ratio. Nuclear Sci. Engng; 36,3;1969; 441-4.

A measurement of the integral value of the fast fission ratio ^{28} is presented for a natural uranium metal single rod having a radius of 6 mm imbedded in graphite. Moreover the thermal and fast fission distribution inside the rod have been obtained from the γ-ray activity from the uranium foils. The spatial distribution of ^{28} was evaluated from these data also.

FISSION-MEASUREMENT

63. ALKHAZOV (ID) etc. Measurement of cross-section of fission of ^{233}U by 16.6 Mev neutron Neitronnaya Fizika. (Conference on Neutron Phys. Pt. IV Kiev USSR 28 May-1 June 1973.

Measurement of fission cross section for ^{238}U by 14.6 Mev neutron was carried out by the method of associated particles. Neutron were obtained at low voltage neutron generator according to the $^{3}H(d,n)^{9}He$ reaction. In the processes of measurements the coincidences between fission fargment and associated particles were registered Fission fragments were registered by means of the combined ionization chamber and scintillation chamber

particles were registered by a plastic scintillation The fission cross section were obtained was equal to 1.17 ± 0.01 barns.

64. COHENSEDGH (F) etc. Fragment energy depends biases ionization chamber measurements of fission cross section. Trans.Am.Nucl.Soc. 19; Oct 1974; 420 p.

This article shows that for these resounances that have been lower than average fragments energies, ionization chamber measurements introduce a certain bias which modifies the cross section of the fission.

65. FURSOV, B.I. Measurement of the U^{238} and U^{235} fission cross section ratios at neutron energies ranging from 1.4, 7.4 MeV Neitronnaya Fizika(All union conference on Neutron Physics), Pt. IV Kiev USSR 28 May-1 June 1973. 3-12 P.

Measurements of the fission cross section ratio of the U^{238} and U^{235} were carried out in the 1.4 to 7.4 MeV region using double ionization chamber. Neutron were produce by the use of a Van de Giraaf generator $T(p,n)He^3$ and $D(d,n)He^3$ reaction were employed. The total unceftainity is about 2.5%.

66. GIONIN(N N) Fission of oriented U^{235} nuclei. Zh. Eskp. & Teo. Fiz. Pis'ma. 20,7; 5 Octo 1974,503-7 P.

The results are reported of measurements of the angular anistropy of fragments from the fission of oriented U^{235} nuclei by neutrons of thermal energies 10, 50,80,100,150 KeV. Anistropy for non oriented nuclei were also measured for neutron energies 50,80, 150 KeV. The bearing of the results on existing nuclear models is discussed.

67. POENTIZ(WP) Measurements of the U^{235} fission cross section in the KeV energy range. Proceedings of a conference on neutron cross section and technology vols. 1 & 2 Washington, 4-7 March 1968.

The energy dependence of the fission cross section of U^{235} was measured in the range 30-1500 KeV. This dependence is important due to the increasing emphasis on fast reactors and due to the significance of thin

cross section as a stand and in cross section experiments.

68. SATO(S) etc. Measurement of fission fragment deposition efficiency by ethylene dosimeter. J.Nucl.Sci. & Technol.10,9; Sept,1973; 577-80. Ethylene has been studied as a chemical dosimeter for r-range and reactor radiation. Little L.E.T. effect is expected from this dosimeter, since the hydrogen yield, G(H2), from ethylene is the same for gammas and fast neutrons present in reactor radiations, possessing broad energy spectra. Ethylene was irradiated in a capsule in the presence of nuclear fuel in a nuclear reactor by means of an in-pile-irradiation apparatus. The calculated kinetic energy of fission fragments absorbed in ethylene was correlated to the amount of hydrogen formation under experimental conditions which characterised the escape of fission fragments from fuel and their reentry into capsule.

69. SAUSSURE(G.De) PEREZ(RB) and MOORE (MN) Auto correlation technique for determining the averave level spacing of the intermediate sub threshold structure in the fission cross section of ^{235}U and ^{239}Pu Phys.Letters. 32B,7; 1970; 413-14.

The interpretation given to the correlogram of ^{235}U and ^{239}Pu fission cross section is questioned as to its validity to estimate the average level displacement in the strutinsky well, appearing in the fission barrier for highly deformed nucle

FISSON-MINERALS

70. KAUL(S L) and SINGHVIRK (H) Optical detection of fossil fission tracks to precambrian age minerals. C.R. Hebd. Seances Acad. Sci B. 279, 18, Oct 1974 477-8 p.

Fossil fission tracks, induced by the spontaneous fission of ^{238}U contained in micaceom minerals have been detected. It is shown that this study is useful for the estimation of the amount of Uranium and subsequently, their age.

FISSION, PHENOMENA-TOOLS

71. IYER(RH) Solid-state track detectors. A nodel tool for the study of fission phenomena. J.Chem. Educ. 49,11, Nov. 1972, 742-5.

An undergraduate experiment for the determination of the ^{235}U content of natural uranium using a solid-state track detector is described.

FISSION-PLASMA

72. MOHL(F) etc. Production of a fissioning Urnaium plasua.
Trans.Am.Nucl.Soc. 17; Sept, 1973; 8-9.
The radiative properties of a fissioning uranium plasma are needed for applications to nuclear pumped lasers and gas core reactors, among other. To produce a fissioning urnaium plasma at high temperature and pressure, the intense burst of 2.5 MeV neutrons (10^{17}n/sec) from the D-P reaction is used in a plasma-focus apparatus.

FISSION-PRODUCTS

73. EVANS (AV) and EAST (LV) Equilibrium spectrum of delayed neutrons from fast fission of ^{235}U. Trans.Am. Nuclei.Soc., 19 oct. 1974. 306-7 P.
A ^{3}He neutron spectrometer has been used to measure the equilibrium energy spectrum of delayed neutron from Sub-MeV fission of ^{235}U. The delayed neutron spectrum is seen to have a complex line structure as observed by Shalev(1872) and by Sloan and Wood ruff(1972). Neutron energy peaks at 71,78- and 937 KeV correspond to peaks previously observed. The overall shape of the spectrum however, corresponds were closely to that measured by Batchelor and Hyder (1956) them that of Sloan and Woodruff.

74. KLEIN(D) On Cadmium-ratio measurements for U^{235} and U^{233} fission by fission-products Gamma counting. Nuclear Sci. Engg. V 22, 3; 1965; 386-7 P
Cadmium ratios for U^{235} and U^{233} fission as measured by gamma counting the fission products with a scintillation counter are compared experimentally with those measured by detecting the fission fragments directly. The ratios of the cadmium ratios determined by those two methods is 1.005 ± 0.007 for U 235 and 1.007 ± 0.005 for U 233. Thus the differences in thermal and epithermal neutron fission yields does not invalidate this technique of measuring cadmium ratios.

75. LOTT(M) etc. Calorimetrical measures of the power emitted by the fission products of ^{235}U for cooling trines ranging between 70 and 7.10^6 secs. Bull.Inf.Sci. & Tech. 181; May, 1973; 51-9.
A calorimetric measurement of the energy released by the fission products of the thermal fission of ^{235}U for decay trines between 70 and 7.10^6 Ses after one fission is presented. Allowing to the rapid variation of the energy release compared to the respoñse time of the colorimeter, two method have been derived for solving the problems. Experimental measurements have been compared to theoretical calculation based on a recent compilation of fission product data.

76. LOTT(M) Total residual power emitted by ^{235}U thermal fission products. J.Nucl.Energy, 27,9; Sept. 1973; 597-605

New results are presented concerning residual power following thermal fission for cooling times going from 70 to $7x10^4$s. A brief description of the experimental technique and of the methods used to obtained the residual power is given and sources of errors as well as a curve due to one fission are given.

FISSION, PRODUCT-GAS

77. MATSUI (H) etc Fission product gas release in burst region of U monocarbide J.Nucl.Sci.& Technol. 10,8; Aug, 1973; 512-15.

The Xe gas release behaviour in the burst region of UC irradiated to various thermal neutron fluences. In thei-exot the rate of fission product gas (^{133}Xe) release in the burst region was determined under the condition of continuous heating, which permitted direct observation of the rate of the initial burst release.

FISSION PRODUCTS-MASS SPECTRA

78. MOLL (E) etc. Analysis of ^{236}U-fission products by the recoil separation 'LOHENGRAIN'. Nucl.Instrum. and Methods 123,3, Feb.1975. 615-1 7 P.

A mass separater for unslowed fission products is installed at the high flux reactor at Grenoble. Well resolved mass spectra are obtained in the light and heavy fission product groups.

FISSION-PROTONS

79. TRACY (BL) Rb and Cs isotopic cross sections from 40-60 MeV-proton fission of ^{238}U ^{232}Th and ^{235}U
Phys.Rev.C. 5,1; Jan. 1972; 222-34.
The isotopic distrib of Rb and Cs from the fission of ^{238}U, ^{232}Th and ^{235}U induced by 40-60 MeV proton have been measured by means of an on-line mass spectrometer. All the isotopic cross sections show a significant odd-even structure, with the formation of even neutron isotopes being favored. The effect is more pronounced for the neutron ricj istopes. The odd-even effect in the Rb and Cs distrib can be accounted for by a 10 to 15% neutron pairing effect in the prompt yield, and a 2 to 3% pairing effect in the neutron emission. From the mean mass numbers to the Rb and Cs distrib the average total no. of emitted neutron has been estimated for each reaction.

FISSION-RATE

80. MOOS (SP) Time dependent ^{237}Np, ^{235}U and ^{239}Pu fission rates in a thorium assembly during the interval 0 to 200 nos using pulsed ^{9}Be (d,n) source 1. Experiment.
J.Nucl.Energy. 27,11: Nov. 1973; 753-68.

A series of integral pulsed neutron experiments is performed in a .4 x .4 x .4 m^3 metallic thorium assembly in such a way as to allow direct comparison of space independent reaction rates with calculated reaction rates derived from a Code with uses the asymptotic reactor theory approximation to describe leakage. The technique either on the Fourier decompotion of measured space-time dependent reaction rates and the extraction from these of the reaction rate corresponding to the fundamental three-dimensional Fourier spatial mode. The reaction rates measured were the fission rates of ^{235}U, ^{239}Pu and 237Np following a short ( ) burst of neutrons with a mean energy of 2.7 MeV.

FISSION-REACTOR

81. HOWARD, (W.H.) etc. Calculation of potential energy surface for fission and heavy ions reaction. Proceedings of the international conference on Nucl. Phys. Vol.1. Germany, 27 Aug-* Sept 1973, p.594

In a unified treatment of nuclear fission, heavy ion reactions and ground-state masses and deformations several new features are intorduced in the calculation of the nuclear potential energy of deformation. These features involve both the macroscopic and microscopic contribution to the energy, as well as the nuclear shapes that are considered.

FISSION-SPONTANEOUS
See
SPONTANEOUS-FISSION

82. ATTREP(M) and SHERWOOD (DJ) The effect of U (,n) reactions on the ratio of induced fission to spontaneous fission in natural uranium. J. Inorg. & Nucl. Chem. 34,2; Feb, 1972; 435-8.
The effect of beryllium are representative low Z element on the change of the ratio of induced fission to spontaneous fission in natural uranium in significant. For systems containing 0.05 and 0.019. Be with respect to the induced to spontaneous fission ratio was measured as 1.58 and 1.48 . The increase in the neutron flux is attributed to (d,n) reaction on beryllium.

83. REIST (HW) etc Spontaneous fission Helv. Phys. Acta. 46,4; Dec. 1, 1973; 440.
The spontaneous fission of ^{235}U was investigated by means of a rotation chamber. A new value for the lower limit of the half life reported is about ten times higher than previously published values.

FISSION-TERNARY
See
TERNARY-FISSION

84. ANTANASIJEVIC (R) etc Mass distrib of fragments from the tenary fission of ^{235}U induced by thermal neutrons. Fizika. 6, Suppl (received: Dec.1974).8p.
An investigation of the ternary fission yield and the

mass distrib of ternary fission fragment was carried out with a solid state track detector sensitive to particles of A 16. The yield of ternary fission with respect to binary fission was found to be $(4 \pm 0.2) \times 10^{-5}$ The mean value of the masses of ternary fission fragments are $M_1 = 36$, $M_2 = 72$ and $M_3 = 128$.

FISSION-TERNARY
See
TERNARY-FISSION

85. ANTANASIJEVIC (R) etc Ternary fission induced by protons of 12.2 GeV on V, Th, Pb, An, Pt, Sn and Ag nuclei.
Proceedings of the 8th International conference on Nuclear photography and solid state track detectors. Vol. II Bucharest, Romania, 10-15-July 1972 (Bucharest, Romania. Inst. Atomic. Phys. 1972) 59-62.
Ternary fission induced by 12.2 GeV protons is analysed in solid state track detectors as a function of the atomic mass of the target nuclei. Basic characteristics of ternary fission are discussed. The cross-section for ternary fission os fome elements that were analyzed are given.

86. DeBRUYNE(P) Thermal neutron-induced ternary fission of 235U. Int. J. Appl. Radiat & Isotop. 22, 1, Nov. 1971; 647-52.

In order to obtained further evidence for or against the existance of ternary fission, in which a heavy nucliate fission fragments into three large charge particles, in place of usual two, radiochemical yields were sought. The possibly of slow neutron fission of ^{235}U in three fragments have been studied by any investigators with a variety of techniques. The tripartion into three comparable mass fragment should however not be confused with the more frequently occuring fission process in which a light charged particle is simultaneously emitted. It may be concluded from the review that additional evidence is required to establish with certainty of the triparation and that the frequency of such events must be very low; the yield is probably less than 10^{-10}. Identification of a realinuclide which cannot be produced by reaction other than fission should provide evidence for the process of course, the formation of such a product by binary fission should be ruled out.

37. FRANZ (EM) and FRIEDLANDER (G) Cross section for the production of ^{84}Rb, ^{132}Cs and ^{136}Cs from thorium and Uranium by 28.5 GeV proton. Phys.Rev.C.4,5; Nov,1971; 1671-3.

Absolute cross sections for the formation of ^{84}Rb ^{86}Rb, ^{132}Cs and ^{136}Cs in uranium and thorium interaction with 28.5 GeV protons were determined by r-ray counting of chemically separated samples. The cross section obtained are as follows for Urain : ^{84}Rb 6.55 ± 0.37 mb. ^{86}Rb, 6.78 ± 6.37 mb ^{132}Cs, 1.30 ± 0.06 mb; ^{136}Cs, 1.13 ± mb; for Urain ^{84}Rb, 6.88± 0.33 mb ^{86}Rb, 7.27 ± 0.34 mb; ^{132}Cs, 10 ± 0.10 mb; ^{136}Cs, 2.64 ± 0.15 mb.

88. KUGLER (G) and CLARKE(US) Mass spectrometric measurements of 3H, 3He and ^{4}He produced in thermal neutron ternary fission of ^{235}U, evidence for short-range ^{4}He. Phys.Rev. 6 S,2; Feb, 1972; 551-60. The mass spectrometric technique has been used to obtained relative and absolute yield for ^{3}H, ^{3}He and 4He and energy distribution for ^{3}H and ^{4}He emitted in ternary fission of ^{236}U. Evidence has been obtained for a short-range component of 4He. The ^{3}He /^{4}He ratio is lower by 2 to 4 order of magnitude than the value previously found in studies of other fissile nuclides. 3H/^{4}He lower by about a factor of 2 then values obtained for 136 U using other experimental technique. Energy distribs obtained for long range ^{3}H and 4He particle are in agreement with results from the experiment.

FISSION-TERNARY

89. KVITEK (J), POPOV (YUP) and RYABOV(YUD)
Ternary fission of U 235 by resonance neutrons.
Yadernaya Fizika. V7, 4; 1965; 677-81 P.
Ternary fission of U 235 by 0.1-50 eV neutrons was measured in the JINR pulsed fast reactor, according to the time of flight method, with a resolution of .66 sec/m In contrast to other investigations concerning the ternary fission of U235 in the region, the resonance neutron/ternary fission event was identified according to the coincidence of one of the fission products with a light long-range particle.

90. NEFEDOV(VN) etc. The angular spectra of prompt neutrons in the ternary fission of U235 nuclei.
Yadernaya Fizika. V 3,3; 1966;465-97
The spectra of prompt neutrons from the ternary fission of U235, emitted at angle 0 and 180 to the direction of the long-range particles, were measured by the time-of-light method. An analysis shows that 27 ± 5% more neutrons are emitted in the direction of flight of the particles, than oppositely. The neutron spectrum internary fission is similar to the two-particles fission spectrum. The mean energy and mean number of prompt quanta in the ternary fission of U235 has been determined.

FISSION-TERNARY
see
TERNARY-FISSION

91. VATER (D) etc. Some angular distributions of fission fragments observed in ternary fission induced by 540 MeV Fe on uranium Radio.chem. and Radio anal Lett. 19,1; 13 Oct 1974, 84-94 P.

Angular distribution of fission fragments originated from ternary fission in the reaction (U + 540 MeVFe) have been measured. Mica was used as fragment detector. The distribution of angles normal to the beam direction is packed quite a different angular distribution. The classification of ternary fission events into certain classes with spcific classes with specific angular distribution is discussed.

FISSION-TERNARY AND BINARY
See
TERNARY AND BINARY-FISSION

92. ANTANASIJEVIC (R) etc. An analysis of the binary and ternary fission of U induced by 12.2 GeV protons. Z. Phys. 254,2; 1972; 106-11.

To binary and ternary fission of U induced by 12.2 GeV protons has been investigated with a polycarbonate detector registering the tracks of particles with mass number A 16. The basic characteristic of binary and ternary fission are discussed and the corresponding cross-sections are given. The values of the cross-section for binary and ternary fission are calculated to be = (915 ± 120) mb and = (12.8 ± 2.5) mb respectively.

93. BECKER (HJ) etc Ternary and binary fission in the interaction of U with 9.6 MeV/nucleon iron ions. Proceedings of the International conference on Nuclear Phyics. Vol.1 (Extonded abstracts), Munich, Germany, 27 Aug-1 Sept 1973, p.601

An experiment with 9.6 MeV/N Fe ions was carried out to investigate nuclear interactions and the results were compared with similar experiments using 9.5 MeV/N Ar ions.

94. KOTOV (AA) etc G.G.Angular correlation of fragments from binary nuclear fission induced by 1 GeV proton Sov. J.Nucl.Phys.

The extracted proton beam of the Leningrad Nucl Phys institute synchroncycloton was used to measure the angular correlations of the binary fission fragments and their energies by means of mosaics of the surface-barrier detector. The ratios of the fission cross-sections for a number of nuclio to the fission cross-section of 238 U were determined.

FRAGMENT - MASS - DISTRIBUTION

95. NAKAGOME(Y) etc. Measurements of fragment mass distribution for ^{237}U and ^{235}U thermal-neutron fission. Annu.help.Res.React. Inst. Kyoto Univ.(Japan).5;1972; 59-65 (received:Nov.1972)

With the development of solid state detectors of good energy resolution and with recently developed energy calibration techniques, it has become possible to perform measurements of fission fragment energies with nearly equal energy resolution compared to the time-of-flight method. The initial fragment mass distribution for ^{233}U and ^{235}U thermal neutron fission obtained by means of double energy measurements using silicon surface barrier detector are given. The fragment kinetic energies were analyzed using a subcell method, because of the insufficient channel numbers of two parameters pulse-height analyzer used.

96. SERGACHEV (AI) etc Influence of excitation energy on the distribution of fission fragments of U^{233} in masses and kinetic energies. Sov. J. Nucl. Phys. 16,3; 1972; 475-83.

The yields and kinetic energies of fragments from U^{233} fission by mono energetic fast neutron were studied for the energy interval 0 En 6MeV The results are being discussed from the view point of the influence of structufe peculiarities of the splitting nucleus and nuclei-fragments on the yields and kinetic energies.

FUEL-NUCLEAR
See
NUCLEAR-FUEL

97. ROAKE(WE) Fuel manufacture and development Nucl News (special issue) 14,10; Oct.1971;779-9. Discuss the economic virtues of fuel cycles and fabrication methods of varisus nations.

GAMMA-RADIATION

98. GRITCHENKO(ZG) etc r-radiation of some rare earth elements produced from U fission by heavy ions
Soviet.J.Nuclear.Phys. 10,5? 1969; 929-39.
Rare earth isotopes with half life period from 1 hour upto 1 year were extracted by means of the radiochemical methods from the U^{238} sample exposed to the many-change ions. C^{12}, Ne^{20}, Ne^{22} and Ar^{40}. The elements from La upto Gd were separated by means of the electromigration ratios method. The r spectra in the energy region 50-2000 KeV were investigated using the semiconductor spectrometer with the Ge(Li) detector. It is shown that the independent isotopes yield at fixed Z is represented by Gaussian distribution. The position of the maxi and the width of isotope distribution indicate to that at fission of heavy nuclei the synthesis of neutron-deficient and neutron and neutron-rich nuclei is rather effective.

99. CORVI (F) etc Low energy r-rays and spins of ^{233}U neutron resonance.
Nucl.Phys.A.A203, 1; March 12, 1973;145-63.
Low energy prompt r-ray spectra in the range 95-670 KeV have been measured for forty-one ^{235}U neutron resonances selected by time-of-flight in the neutron energy range 15-58eV. Discrimination against the natural r-activity of ^{235}U has been obtained by means

of a coincidence technqiue. The spectra show a very complicated structure owing to a few capture and many fission r-rays have been used for spin assignments of fourteen resonances with small fission widths. Some conclusions are drawn about the spin dependences of average fission widths, anisotropy of fission fragments and symmetric fission yields.

GAMMA RAY-SPECTRA MEASUREMENT

100. VERBINSKI(V) etc Prompt r-rays from ^{235}V(n,f) and spontaneous fission of ^{252}Cf Phys Rev.C.(USA)7,3; March, 1973; 1173-85.

The spectra of prompt r-rays from ^{235}U (nf), ^{239}Pu(n,f) and ^{252}Cf(Sf) emitted at 0-1onsec after fission were m measured with C 4-nsec tune resolution. A r-ray spectrometer with a near-Gaussian response was used over the entire energy region, and prompt neutrons from fission were positively rejected by the time of flight. The measured r-ray spectra show a systematic softening with increasing mass no for ^{235}U, ^{239}Pu and $^{252}C_f$. The average photon energy above .14 MeV is .97 ± 0.05, 0.94 ± .05, and 0.88 ± .04 MeV/Photon for thermal neutron fission of ^{235}U and ^{239}Pu, and spontaneous fission of $^{253}C_f$, respectively.

GAS, ISOTOPES

101. BOCQUET, (J.P.) etc On live measurements of raregas fission yields in 14 MeV neutron fission. Nucl.Phys. A 189,3; 1972; 556-76.

The independent and cumulative fission yields of rare gas isotopes produced from the fission of ^{233}U ^{235}U, ^{238}U and ^{232} Th by 14 MeV neutron have been measured by means of on-line isotopes saparation. Chain yeidl can be deduced from the cumulative yields and Gaussion curves fitted to the independent yield distribution. Values of Z_p-Z_{uc} and have been compared with those obtained from other fissioning systems. The total no of neutron $_{tot}$ emitted in ^{233}Th fission has been estimated.

HALICITY-FORMATION

102. ERKELENZ(E) Momentum space calculations and helicity formation in nuclear physics. Nucl.Phys.A. A176,2; Nov, 1971; 413-37

Using the free reaction matrix R and Brueckner-Goldstone reaction matrix G the two-nucleon scattering and nuclear matter problem is presented in the helicity state formation. The helicity and partial wera state matrix elements of the most general nuclear-nucleon potential given in the momentum space are calculated.

ISOMERIC-FISSION

103. HOOSHYAR(MA) and MALIK(FB) Total spontaneous and isomer fission half-lives of ^{234}U, ^{236}U and ^{260}Pu Phys.Lett.B. 39 B,7; April, 1972; 495-8.

Using the recently proposed coupled channel delay theory the authors have reproduced the observed absolute yield curves; total decay probabilities from the spontaneous and the isomeric fission states of ^{234}U and ^{240}Pu and the average kinetic energies. Their predicted yield curve for the decay of isomer fission state seems to be in agreement with preliminary observation.

104. HOOSHYAR(MA) and MALIK(FB) Charge distribution and average masses in the spontaneous and isomeric fission of ^{234}U, ^{236}U and ^{240}Pu. Phys.Lett.B.55B,2;3 Feb 1975, 144-6p.

Percentage yields for various elements and their associated average masses in the spontaneous and isomeric fission of ^{234}U, ^{236}U and ^{240}Pu are claculated for the same set of parameters which account for the percentage yield of different masses, half-lives and the kinetic energy spectra of their respective fragments.

105. KASKY (E) etc Search for r-branch in the ^{236m}U fission isomer decay Commentat.Phys.Math.(Finland) 42,4;Dec, 1972; 226p.(Proceedings of the Annual conference of Finish Physical society) 19-19 Feb 1972.

The fission decay of a ^{236m}U isomer with a life time of 130 ± 15 m and an excitation energy of 2.3 MeV has been well documented. From comparison of delayed fission yield to calculation of the production cross-section it appears that the r-decay is expected to be the principal mode of de-excitation of thin isomer. The conclusion to be drawn from careful analysis of the result is that no r-rays are observed with the right half-life in the energy region 0.8MeV 2.7MeV. Quantitatively one can say that for E 1MeV isomer So b and for E_r MeV isomer 12 b.

ISOMERIC, FISSION-XRAY

106. BROWNE (JC) and BOWMAN(CD) Investigation of r-ray emission proceeding isomer fission of ^{236}U. Phys. Rev. Lett. 28, 10; March, 1972; 617-20.

Measurements were made to detect r-rays proceeding isomeric fission in ^{236}U induced by eV-range neutrons captured in ^{235}U. A limit of 6 x 10^{-5} was placed on the ratio of the rate of isomeric fission events with prefission r-rays to the rate for prompt fission events. This experiment provides direct evidence that the penetration of the outer barrier is much greater than that for the inner barrier for 3-and4-states in ^{236}U.

ISOMERS

107. SHAH (GB) TOMITA (I) and YAFFE(L) Isomer ratios of ^{134}Cs formed in the fission of ^{233}U and ^{235}U by protons of energies 20-85 MeV. J.Inorg.Nuclear. Chem. 31,12; 1969; 3731-7.
The isomer ratios of ^{134}Cs formed in the fission of ^{233}U and ^{235}U by protons of energies 20-85 MeV have been determined experimentally. Calculations have been made for these isomers ratio on the basis of a statistical theory of the spin distribution of the primary fragments. The root mean square angular momentum characterising the spin distribution of the primary fragments, varies between 12 tiat 20-30 MeV and 18 to at 85 MeV in ^{233}U fission, where as it is about 16 to in ^{235}U fission through out this energy region.

ISOTOPES

108. BUDICK(B) etc. Moun-and pion-induced fission of uranium isotopes. Phys.Rev.Letters 24,11,1970;604-7.
The authors have measured the energy distributions of fission fragments following formation of muonic and pionic ^{233}U and ^{235}U. They have confirmed earlier results on the mean lives for muon capture by ^{235}U and ^{238}U and extended the study to ^{233}U, Additional data have also been obtained on the process where by a muon induces fission by ransferring its excitation energy to the nuclear in a radiation less transition to the Is level.

108. BOCQUET (JP) etc. On-line measurements of the rare-gas fission yields in 14 MeV neutron fission Nucl. Phys. A. A189, 3; 1972; 556-76.

The independent and cumulative fission yields of rare-gas isotopes produced from the fission of ^{233}U, ^{235}U, ^{238}U and ^{232}Th by 14 MeV neutron have been measured by means of on-line isotopes separation. Chain yields can be deduced from the cumulative yields and Gaussion curves fitted to the independent yield distributions. Value of Zp-Zuc and have been compared with those obtained from other fissioning system. The total no. of neutron, V_{tot}, emitted in 232Th fission has been estimated.

109. FRANZ(H) HERMANN(G) KRATZ, JV and KRATZ K.L. Decay properties and yields of short-lived fission products in the 50 and 82 neutron-shellregion in thermal neutron induced fission of ^{235}U. J. Phys. (France) 33, 8-9; Aug-Sept 1972; 31 P (European conference on nuclear phys.) Rapid ratio chemical separation procedures were used to identify among the fission products of ^{235}U, short-lives down to about one sec. independent and cumulative fission yields of a no. of these nuclier were measured.

ISOTOPES

111. HAGEBO (E) and RAVN(H) Recoid properties of autimony isotopes produced by the reaction of 570 MeV and 18.2 Gev protons with U. J.Inorg.Nuclear Chem. 31,9; 1969; 2649-47.

Using the method of thick catcehrs, the ranges and recoil properties of 13(12) autimony isotopes between A = 115 and A = 131(130), have been measured for the reaction of 570 MeV (18.2 GeV) proton with U. The kinetic enrgies T are almost independent of product mass number at 570 MeV but show a strong dependente at 18.2 Gev the highest isotopes having energies for productive of autimony isotopes are almost equal at 570MeV and 18.2 GeV and fil well to straight lines of the form.

112. IYER(MR) and GANGULY (AK) Neutron evaporation energy, distribution in indidividual fission fragments. Phys. Rev.C.5,4; April, 1972, 1410-21.

Using isotopic probability distrib of fragments as given by a model for the fission process andthose of product as calculated from published product charge distrib parameters, a new procedure is developed for obtaining the no. of neutron evaporated from individual fragments of 235U.

113. LARSON(CE) Uranium enrichment. Nucl.News(Special issue) 14,10; Oct.1971; 74-6.

Reviews the present trends and techniques employed in the enrichment of uranium isotopes including an improvement separation nozzle process.

114. TOMITA(I) and YAFEE(L) Nuclear charge distribution in the fission of 233U by protons of medium energy. Canad. J.Chem. 47,16; 1969; 2921-32.

Independent yields and excitation functions have been determined for the formation of cesium isotopes with masses 129 A 139 in the fission of 233 U with protons of energies between 20 to 80 MeV. The energies at which the various excitation function reach their maxima have been compared with those obtained for the same isotopes from fissioning systems with targets of different neutron to proton (N/Z) ratios.

115. TRACY(BL) etc. Rb and Cs isotopic, cross section from 40-60 MeV proton fission of 238 U, 232Th and 235U. Phys.Rev.C. 5,1, Jan.1972; 222-34.

The isotopic distrib of Rb and Cs from the fission of 238U 232 Th, and 235 U induced by 40 to 60 MeV protons have been measured by means of an on-line mass spectrometer. All the isotopic cross-section show a significant odd-even structure, with the formation of eve-neutron isotopes being favoured. The effect in made more pronounced for the neutron rich isotope. The odd-even effect in Rb and Cs distrib can be accounted for by a 10 to 15% neutron pairing effect in the prompt yield and a 2 to 3% pairing effect inthe neutron emission from the mean mass numbers of Rb and Cs distribution, the average total no. of emitted neutron has been estimated for each reaction. The information together with result on neutron emission as a function of fragment mass, has allowed the mean mass no. to be corrected for prompt neutron emission.

MASS-DISTRIBUTION

116. BOGDANOV(VG) On the question of the mass distribution of LRP-fission products. Yadernaya Fiz. 15,2; 1972; 209-12 In Russion English translation in Soc.J.Nucl. Phys.(USA)

The values of a coefficient K which takes into account the particle recoil effect at the construction with $E_s m = KE_n m_n$ formula of the LRP fission products mass distribution in calculated for different fragment mass ratios of U235 LRP-fission by thermal neutrons and U238 by fast neutrons.

117. BORDEN(KD) and KURODA(PK) Mass distribution in the fission of 233U by 14.8 MeV neutron. J.Inorg.Nuclear Chem. 31,8; 1969; 2623-5.

The only available data on the mass distribution in the fission of 233U by 14-15 MeV neutrons are those reported by Bomyshkin et al(1961,64) who measured the yields radiochmeically for ten mass chains. The authors measured in this work the 233U fission yields at 14.8 MeV neutron energy for twenty two mass chains. The mass distribution is intermediate between those of 14-15 MeV neutron induced fission of 232 Th, and in the not observed in the fast neutron-induced fission of 233U.

MASS-SPECTRA

118. KONONOV,VN etc. Absolute measurements of for 235 U and 239Pu in the range of neutron energy of 10 KeV to 1 MeV So.At.Energ.32,1; Jan,1972;85-7.

With the help of spectrometer new value for U235 and Pu 239 were determined. Charge cadmium and scintilating liquid detector were used for detecting radiative capture of neutrons and instaneous quanta fission. The value for represent average reading of five measurements for U235 and 9 measurements for Pu239, taken indpendently. The absolute error for including the ambiguity of the measuring set-up is under 15% Good agreement is obtained with other experimental values, measured on the Vando Graaf accelators by similar method.

MATRIX THEORY

119. MIHAILESCU(M) The application of the rank annihilation method in the R matrix theory. Rev.Roum.Phys. 19,10; 1974; 1063-75p.

The collision matrix expression in terms of the R-matrix is adequate for the application of the rank annihilation method. Generalizing the Reich-Moore method(1958) to an arbitrary number of fission channels and using the rank annihilation method ingetting the channel matrix elements, the most general formula of the neutron fission cross-section applicable to N interfering resonances levels and without referring to the number of open fission channels is obtained. The 235 U fission cross-section value computed by thin method for neutron energies less than 20 V are compared with those previously obtained by the Vogt method (1958) A good fit to the experimental data is found.

MEASUREMENT

120. GTONTU(NN) etc LK An installation for measuring the angular anistrophy of alpha decay and fission of oriented actinide nuclei. Instrum. & Exp.Tech 17,1; Jan-Feb.1974. 42-4 p.

An installation is described for performing exp on measurements of the angular anisotropy of radiation and the fission of oriented actinide nuclei. A procedure for growing single crystals of actinide-nuclei. nitrate and a method for depositing layers of radioactive compounds on them are given. The fission fragments and particles were recorded by semiconductor detectors that were maintained at a temp 25 K. Results are represented of measurements of the anisotropy of radiation from oriented 237 Np nuclei and the emission of fragments as a result of the fission of oriented U235 nuclei by thermal neutrons.

121. KOPPIG(DR) and CARTER (LL) Analysis of 239 Pu and 235 U resonance self-shielding experiments. Trans. Am.Nucl.Soc.(USA) 17; Sept.,1973; 491-2.

The resonance self-shielding measurements of Czirr and Bramblett for 239 Pu and 235U have been analyzed with the MCN Monte Carlo Code using cross sections generated from the current ENDF/B-III data.

122. RAFFETY (SJ) and MIHALCZO(JT) Homogenous critical assemblies of 2 and 3% U 235 enriched U in Paraffin. Nucl.Sci & Eng. 48,4; 1972; 433-43

A series of clean critical expts has been performed with homogeneous mixtures of finely divided U(2) F4 or U(3) F4 dispersed in paraffin with H/235U atomic ratios varying from 133 to 1972. The assemblies are constructed in rectangular geometry, and minimum critical masses and volume in cylindrical and spherical geometries are obtained from buckling conversions.

123. RAJAGOPALANI(M) and THOMAS(TD) Emission of alpha particles in the fission of 238U by 16 and 42 MeV protons. Phys.Rev.C.S,4; April, 1972; 1402-9.

The rate of emission of particles in coincidence with fission has been measured for 238U bombarded with protons of energy 16 and 42 MeV. There is a significant increase in the number of particles per fission over thin range. Part of thin increase is due to contribution from the (p, f) reaction. After correction are made for thin process, however there remains an increase of about 20% in the probability for the (p, f) reaction between the low and high-energy measurement.

124. ROTHE(RE) Critical measurements on an enriched uranium solution system. Nuclear Sci.Energy 35,2; 1969;267-76p.

Critical parameters are reported for an essentially unreflected system containing uranium solution and a fixed neutron poison. The uranium solution contained 450.8 of uranium per liter. The uranium was enriched to 93.19 wt% 235 U. The fixed poison was natural boron contained in stainless steel plates and comprised of 1.02 wt%of the plates. The total boron content was varied on successive runs by changing the number of plates. The plates were arranged along parallel chords of the 106.6 cm diam cylindrical experimental tank; they were approximately uniformly spaced. Three types of measurements are reported. The first type provides data on an unpoisoned slab. In the second type, the uranium solution height at critically was less than the height of the plates and provided data on a poisoned solution cylinder.

125. SMITH(IR) and REEDER(SD) Measurements of the absolute value of eta for 241 Pu by the manganese both method. Proceedings of a conference on neutron cross section and technology Vol1 Aug 2 Washington, 4-7 March 1969 589-96.

The absolute value for eta for 241Pu has measured using the manganese bath technique. The MTR crystal spectrometer provided mono-energetic neutrons for measurements at .0253 eV and .060 eV Purity of the monochromatic beam was insured by the operation of a mechanical neutron filter in the Bragg beam. The measurements consisted of comparing the 56 Mn activity induced in the solution by the neutron beam with the activity induced by fission neutron emitted when the low energy beam was absorbed in the fissible sample.

126. TASA (KS) and ALTREP(M)
Radiochemical determination of the first neutron flux in uranium assemblies. J. Inorg. and Nucl.Chem. V.36 no.8 Aug.1974, 1699-703 p.

Zinc was introduced into pure Ur salt assemblies as target material for the formation of fast neutron reaction product inorder to determine the fast neutron fluxalities determine in three sample was .029 + 0.003, .070 + .002 and .0094 .003 n/min/gu. The fast neutron flux for these three samples was calculated from reactor theory and found to be .026, .017 and .017 n/min/gU, respectively. This study provides the first direct measurement by activation of the fast neutron flux present ina natural uranium assembly.

MEASUREMENT-DISTRIBUTION

127. POSTMA(H) (n,r) reactions with and neutron-induced fission of oriented nuclei. Proceedings of the 2nd international conference on polarized targets, Berkley, Calif, USA 30 Aug-2 Sept. 1971; 237-46.

The first type of experiments concerns gamma emission after capture of either unpolarized or polarized neutrons by oriented nuclei. In the other experiments the directional distribution of fission-fragments from aligned 233U,235U and 237Np nuclei is studied. The latter give information about the nature of barrier states of highly deformed nuclei.

128. TROUTNER(DF) A comparison of nuclear change distrib in thermal neutron induced fission of 233 U and 235U. J.Inorg. & Nucl. Chem. 37,12; Dec. 1972; 4327-23.

Fractional cumulative yields of fission products are obtained. These are helpful in understanding the nuclear change distrib which occurs during fission Radiochemical measurements of nuclear change distrib in the thermal neutron induced fission of 237 U and 235 U are compared.

MEASUREMENT-GAS
See
GAS-MEASUREMENT

129. BREUMER(WD) and WASHINGTON(ABG) Measurement of fission gas release rates from a Uranium dioxide fuel pin during irradiation in a fast reactor. J.Br.Nucl. Energy Soc. (GB) 12,4; Oct.1973; 449-54.

An expt has been carried out in the Dounreary fast reactor to measure continously the fission gases released from a long U dioxide fuel pin irradiated to a burn-up to 2%. The gases were swept by a helium purge from the pin to the reactor top where they were analysed by bottle sampling and in line spectrometry. Measured release rates increased with isotopic half life from about 0.03 % for Krypton -89 to 60% for stable gases. Although the release rates varied throughout the irradiation they did not increase significantly with rapid changes in reactor power.

MEASUREMENT-LUNAR NEUTRON
SEE
LUNAR NEUTRON-MEASUREMENT

130. WOOLUM(DS) and Burnett (DS) In-situ measurements of the rate of 235U fission induced by lunar neutrons. Earth & Planet.Sci.Lett 21,2; Jan 1974; 153-65.

The depth profile of the neutron-induced fission rate of 235U was directly measured to a depth of

350 g/cm^2 by the Apollo 17 Lunar Neutron Probe experiment. The fission rate rises shaply from the surface to a broad maximum from 110 to 150 g/cm2 and drops off at greater depths. The shape of theoretical depth profile of Lingenfelter etal. fits the measured capture rates well at all depths. The absolute magnitude of the experimental fission rates are (1) + 17)% lower than those calculated theoretically.

MEASUREMENT-MASS

131. KOTIL(J) MORAVE(A) and MEUCL(J) The determination of %burn up of the nuclear fuel on the basis of mass spectrometric measurement 1. Measurement of percentage of fissions of U235 Jad.Energy. 19,12; Dec.1973; 400-3. The paper describe the determination of burning up 235 U on the basis of measuring the decrease of 235U and increase of 236U in the irradiated fuel. The developed method of 236U in the irradiated measurement of the ratios 235U and 236U in the initial and irradiated fuel. Two samples of the nuclear fuel were analyzed by their method and the resultsof the burn-up obtained were compared with that determined radiochemistry.

MEASUREMENT-MASS
See
MASS-MEASUREMENT

132. NEOLpo(U) Abegg (R) and VAGNER(R) The measurements of the reaction time of 238 U(n,2nf) using 14 MeV neutron Helv.Phys.Acta. 46,6; 1 Dec, 1973; 445.(Swiss Physical Society Meeting, Switzerland,4-5,May 1973). The angular distributions of fission fragments which were emitted from UO2 single crystal under the bombardment of 13.4 MeV neutrons were evaluated with the aid of glass plates.

MEASUREMENT-MASS, DISTRIBUTION

133. NAKAGOME(Y) etc Measurement of fragment mass distributions for 233U and 235U thermal-neutron fission. Annu.Rep.Res.React. Inst.Kyoto Univ(Japan)5; 1972; 59-65 (received :Nov,1972).
With the development of solid state detectors of good energy resolution and with recently developed energy calibration techniques it has become possible to perform measurement of fission fragment energies with nearly equal energy resolution compared to time-of-flight method. The initial fragment mass distribution for 233U and 233U

thermal-neutron fission obtained by means of double-energy measurements using silicon surface barrier detectors are given. The fragment kinetic energies were analysed using a subcell method, because of the insufficient channel numbers (32x32 channels) of the two-parameter pulse-height analyser used.

134. SULLIVAN, (IN,J) and WEHRING(B.W) Study of the use of particle channelling in time of flight fission-fragment mass-yield measurements. Nucl.Instrum. and Methods, 116,1; 15 March, 1974. 29-39.

A direct physical measurement of the mass distribution in the thermal neutron fission of 235U was made using the single time-of-flight method and particle channelling was employed in an attempt to achieve good energy resolution to give a mass resolution of better than 1 amu.

MEASUREMENT-METHODS

135. MARK(E) etc Comparative determination of Ur Content by the fission-track method and by delayed neutrons. Acta-Phys.Austrica; 40, 3-4; 261-71P Dec.1974.

Both methods have been examined as to their accuracy reproducibility, sensitivity, required mass of the sample and cycle time per sample. The lower limit of detection for Ur is .3 ppm when applying the method of delayed neutron and 10^{-3} ppm for the fission track method.

MEASUREMENT-NEUTRON

136. KIMURA (I) KOBAYASHI(K) and SHIBATA(T)
Measurement of average cross-sections for some threshold reactions by means of a small fission foil in large thermal neutron field.
J.Nucl.Sci. & Technol.10,9; Sept, 1973;574-7.
Average cross-section measurements were made on a U-AR foil in an irradiation room large enough to before of reflected flux perturbations. Errors due to using reference reactions are eliminated. Reactions rate was calculated by a Monte Carlo method.

MEASUREMENT-NEUTRON
See
NEUTRON-MEASUREMENT

137. MULLER (R) etc. Search for fission shape isomers in (n,f) reactions induced by neutron of about 1MeV. Phys. Lett.B. 48B,1; 7 Jan.1974;25-7.

Upper Limits for the isomer of prompt fission ratio were measured for the compound nuclei 230U and 240Pu ecitied by neutron with energies in the .5-2.5 MeV region. From these data the difference in the barrier heights of the double-humped fission potential were calculated with a modified statistical theory.

138. SARIN(MV) etc. Energy depence in fissioning U235 with fast neutrons. Yad.Fiz.16,6; 1972; 1161-6.In Russian. English translation in :Sov. J.Nucl.Phys. (received:Jan 1973)

The results of measuring in fissioning U235 with 0.7-6 MeV neutrons are reported. The measurements were made at the Electron linac with a time-of-flight method-using a liquid scintillation detector. The calculation of energy dependence in U235 fission according to the statistical model is presented.

MEASUREMENT-TECHNIQUE

139. PATRICK(B.H.) and BOWEY(EM) A new technique for the measurement of photonentron angular distribution: Nucli.Instrum. & Methods. 120,2; Sept.1974; 245-9p.

A new technique for measurement of photoneutron angular distrib using track detector is described. Makrofob-uranium-Marrafol sand-whiches are placed around the sample being studied. Fission fragment produced by fast neutrons interaction in the Uranium damage the Makrofol and by counting these tracks angular distribution can be obtained. A measurement of the photo disintegration of deuterium serve to demonstrate the technique.

MEASUREMENT-VIBRATION

140. McARTHUR(DA) and TOLLEFSRUD(PB) Measurements of optical gain on vibrational transitions of CO gas excited only by fission fragment. Trans.Am.Nucl.Sec.19; Oct.1974;356 p.

There is a leser medium that can be pumped with nuclear reaction products Although the existance of a population inversion has been inforced from some spectroscopic measurements in only He-Ne and He-Ne-air mixture has a measured optical gain been reported.

METHODS-ANNIHILATION

141. MIHAILESCU(EM) and PETRASCU(M) Multilevel calculation of 235U neutron fission cross-section usingthe rank annihalation method.

Rev.Roum.Phys.18,10; 1973; 1219-29

Using the rank annihilation method, recurrence formulae for calculating the level matrix elements are given. A multilevel expression of the neutron fission cross-section is obtained. The iteration procedure depends on the number of the open fission channels. The 235 U fission cross-section forneutron energies less than 2 ev is computed in two cases. One and two open fission channels. The results are compared with those obtained using Reich-Moore expressions.

NEUTRON

142. ALEXANDER,P. Independent yields of 131,135Xe in the fission of 235U,238U and 239Pu by 14MeV neutrons.

Nucl.Phys.A. A 198, 1; Dec, 1972, 228-36

The direct fission populations of states in 133,135Xe have been measured for fission induced by 14MeV neutrons Targets consisting of metal foils of 235V,238U and 239Pu were separately encapsulated and irradiated for periods of 1 to 8 min in a flux of 1.5 x 10" n/cm2s. The Xenon isotopes of interest were extracted from the bulk fission products within 3 to 12 min after irradiation. Computer analysis techniques were employed to extract the independent fission yield values from data.

143. BOLDEMAN, J.W. MUSGROVE,AR deL.and WALSH, R.L. Prompt neutrons from 236U fission fragments. Aust.J.Phys.24; 6; Dec, 1971; 821-33.

Measurements have been made of prompt neutron emission in the thermal neutron fission of 234U and the mean neutron emission per fragment has been obtained for particular values of the fragment mass and total kinetic energy. A direct neutron counting method was employed and a comparison is made with data from previous experiments of this type.

144. DERUYLLER(AJ) Research at CBNM to improve the accuracy of neutron standard cross-section. Neitronnaya Fizika. (All union conference on Neutron Phys) Pt IV Kie USSR 28 May-I June 1973.

Reliable neutron cross section to which can serve as standard cross section for the relative determination of other cross sections needed in reactor design are of great importance. Absorption and fission cross section have been studied for the purpose at CBNM. Reference fission cross sections were determined upto about .5% at 2200 m/s neutron velocity and normalisation throughout the resonance region was performed upto 1%. Comparison of different data sets reveal the need for a severe selection of data to be entered in the data files.

145. FREHANT(J) SOLEILHAC(M) and MOSINSKI(G) Measurements of the mean number of prompt neutrons emitted in the fission of 240Pu and 235U induced by neutrons of energies between 1.5 and 15MeV. Neitronnaya Fizika (Allunion Conference on Neutron Physics, Pt. III, Kiev, USSR, 28 May-1June 1973. 153-64 P.

Using 12 MeV Tandem Van de Graaf accelerator for production of incident neutrons and a big liquid scitillator for detection of fission neutron the authors have measured simultaneously and with accuracy 1.5% (in relative values)the mean number of prompt neutron emitted in the 240Pu and 235U fission reaction induced by neutrons with energy from 1.5 to 15MeV. From the results obtained they could derive the fission cross section of 240Pu relative to that of 235U. They also obtained an accurate value of Up for the spontaneous fission of 240Pu.

146. GARRISON(J.D) Missing resonances in low-energy neutron cross section of fissible nuclei. Phys.Rev.Lett 29,17; 23 Oct, 1972; 1185-8.

A study of simulated fission crosssections indicates that the number of missed levels for fissile nuclei can be considerably larger than has generally been divided. For a nuclear such as 235U with a number of open fission channels and a small level spacing, approximately half the levels are unobserved at 39C neutron energy for a target at room temperature.

147. GREEN(G) On the Fermi age of delayed neutrons Z.Phys. 245,4; 1972; 323-38

For the first time the migrations areas of four single groups of delayed neutrons resulting from the fission of 235U have been measured. The following values for the migration area M2, the age 1.46 at the indium resonance, and the age the for the slowing down to thermal energies have been determined.

148. KLUDEC(GY) and LAJTAI(A) On the average characteristics of prompt neutron emission from fission. Phys.Letters. 30B, 5; 1969; 311-12.

The prodication of obtained by using more accurate expressions for the average neutron energy in terms of a statistical model are compared with the experimental data on the thermal neutron fission of 233U,235U and 239Pu and on the sponyaneous fission of 252Cf.

149. MATHER(D.S) and BAMPTON(P.F.) Evaluation of for 235U Report AWRE 055/71 AWRE, Aldermaston, Berks, England. Aug. 1971 · 22.

An evaluation has been made of direct measurements of for the neutron induced fission of U-235 using data available before January 1971 and evaluated calues entered into a new data file DFN-271 Below 1.75 MeV a non-linear variation is evident with astep-like structure between .7 and 1.4 MeV, a spline fitted curve has been used to describe this region.

150. MIHALCZO(JT) Prompt-neutron tune behaviour in delayed critical coupled uranium-metal cylinders. Proceedings of the international conference on fast critical experiments and their analysis. Argonne, 10-13 Oct. 1966; 237-41.p.

Pairs of identical Coaxial, 27.94 cm dia cylinders of unmoderated and unreflected uranium metal have been assembled to delayed critically with large space between the flat surfaces. The metal was enriched to 93.15 W/o in the 235U isotope. Prompt neutron decay constant of the assemblies were measured by the Rossi- technique, and the results agreed with those predicted by a method in which a pair of equations represented the kinetics of a coupled-care assembly The equations neglected delayed neutrons and assumed space independent kinetics for each cylinder with a time lag to represent the flight time from one cylinder to the other. Multiplication factors calculated for the assemblies using S8 transport theory also agreed with the experimental values.

151. ROSLER(H) PLASIL(F) and SCHMITT(H.W) High-resolution cross section measurements for 236U (n,f) Phys.Lett.B. 38B, 7; April, 1972; 501-3.

The cross section for neutron-induced fission of 236U has been measured in the region of the fission-threshhold, with 7 KeV resolution for neutrons in the energy range 0.5 to 2.6 MeV cross-section maxima are observed at 0.75, 0.95, 1.15 and 1.5 MeV It is possible that these peaks correspond to collective levels in the second maximum of the potential-energy barrier for fission.

152. SCHACHTER (L) etc. An experimental determination of the contribution of U-235 and Pu-239 to the burn up of a plutonigen fuel. Revue.Roum. Phys. 17,6; 1972; 729-37.

The authors present the experimental method used for separate determination of the number of fission produced in U-235 and Pu-239 accumulated by neutron capture respectively, by measuring the activity of the fission products Ru-106, Cs-137 and Zr-95, resulting from the irradiation of the plutonigen fuel elements in the reactor.

153. SURIN(V.M.) etc. Yields and Kinetic energies of fragments in the fission of U233 and Pu239 by 5.5 and 15 MeV neutrons Soc.J.Nucl.Phys. 14,5;1971;935-8.

The measurement are performed of the fragment distribution in masses and K. and at the fiss ion of U233 and Pu239 by 5.5 and 15 MeV neutrons. It is noted the considerable increase of symmetrical fragment yields and the decrease of the mean K. of fragment. The variation of K Es of fragments with different masses are different both in absolute values and in sign.

154. ZAKHAROVA,(V.P) etc. Investigation of 235U fission by thermal neutrons Sov.J.Nucl.Phys. 16,4; 1972; 649-63

Mass and energy distribution of fragments in studying of fission reaction U235 + nther, are presented. Fragments energy was detected in a double ionization chamber with grids. The ratio Peak/valley in the mass distribution not corrected for the apparatus resolution, neutron emission and the background from accidential coincidences, comprises 360.

NEUTRON-ACTIVITIES

156. CAMPBELL(F.T.) and STEEL,(E.L.), Uranium assay by nondestructive neutron activation analysis. Radiochem & Radioquol Lett. 11; 3-4 15 Sept. 1972 745-50

A fully nondestructive neutron activation analysis method for uranium assay in rocks and core samples has been developed. The 1596.6 KeV r-ray of 140La was measured at two different decay times and simultaneous equations used to eliminate the contribution from 139 La(n,r) 140La. The remaining activity measured is the result of the sequence 235U(n,f) 140Ba 140La and is indicative of the U content. No special equipment except the Ge(Li) detector system was needed.

NEUTRON-DEFECTORS

157. COLDWELL (J.T.) etc. 235U enrichment determination using 4He proportional counters. Trans.Am.Nucl.Soc. 17; Sept. 1973; 95-6.

Two new techniques for 235U enrichment determination in UF6-filled cylinders have been developed using 18 atom, 4He proportional counters fast neutron detectors. The development was undertaken in an effort to improve reliability in UF6 enrichment measurements. The first new enrichment technique consists of measuring the passive fast neutron flux emerging form a UF6 cylinder. The second enrichment measuring technique is based on thermal neutron-induced fission of the 235 U in the UF6 cylinders.

NEUTRON-DISTRIBUTION

158. CHOPPIN(C.R.) and KANDIL(A.T.). The nuclear charge distrib of the charged particle fission of 238U J.Inorg. & Nucl.Chem.34,2;Feb.1972;639-42.

The distribution of nuclear charge in the fission of 238U by protons of 11.2 MeV and denterous of 10.6 MeV energy has been studied using Ge(Li) spectroscopy using the criteria of a Gaussian change dispersion curve it was found that the postulate of minimum potential energy best described the data in both system although the proton data was fitted almost as well by the postulate of equal change displacement.

158. NETHAWAY(D.R) and MENDOZA(B) Comparision of yields from fission of 233U,234U,235U,236U and 238 U with the 14.8MeV neutrons.

Phys.Rev.C.6,5; Nov, 1972; 1827-37.

The authros analysed mass-yield distributions from fission of 233U,234U,235U,236U and 238U with 14.8MeV neutrons to study the details of the fission distribution as a function of target mass number at a fairly low excitation energy. The fission yields of individual products, both cumulative and independent, vary smoothly and as expected with uranium target mass number. The over-all distribution of yields becomes significantly narrower as the uranium mass number is increased The average neutron emission associated with the vary-low-yield products is about 3.5,significantly less than the value of about 4.5 for the fission fragments as a whole. This difference may be due to an increase in energy required for reactions leading to the low-yield products. The peak/valley ratio increases by a factor of more than 2 as the mass number is increased from 233 to 238 and decreases linearly with increasing excitation energy, with the even-mass and odd-massuranium isotopes defining lines that are approximately parallel and separated by 1.4 MeV.

159. NETHAWAY (D.R) and MENDOZA(B). Fission of 234U and 236U with 14.8MeV neutrons. Phys.Rev.C.6,5; Nov.1972. 1871-6.

The authors determine mass-yield distributions from fission of U234 and 236 with 14.8 MeV neutrons. They measured the yield of 24 products covering the mass range 66-172 for 236U total chain yields were estimated by correcting for the affects of nuclear charge dispersion in fission. The mass yield curves are similar to those for fission of 233 U,235U and 238U with 14.8 MeV neutrons.

160. RAYABOV(Yu.V) etc. Relative measurementsof in resonance neutron induced fission of U235 and Pu239 Soc.J.Nucl.Phys. 14,5; 1971; 927-34.

Spin dependences is detected in the yield of average number of instant neutrons per a fission for U235 and Pu239 in the neutron energy region 1-40 eV and 5-35eV, respectively.

161. SHIRAISHI(F) and HOSOE(M) Mass distribution of fission fragments from 235U(nth,f) by simultaneous measurement of velcotiy and energy. Nucl.Instrum.& Method. 107,3; March 15,1973;493-500.

The flight time, velocity, energy and mass distribution are analysed, and their characteristic figures, the mean value and the rms widths of the distributions for the individual group of the light (70-117 amu) and heavy (119-160amu) fragments, are calculated

NEUTRON-FISSION

162. DOAN(T.P.) etc On the resonances above the fast neutron fission threshold of 232Th,231Pa and 234U. J.Phys.33,8-9, Aug-Sept, 1972; 13. European Conference on nuclear physics 26 June-1July 1972.

The interpretation of the structure of the fission cross-section curve near threshold is discussed. Resonances appearing just above threshold present great difficulty in interpreation. The author have been attempted on interpretation based on the variation of the inertia parameter by using result of Hoffman and Dietrich. Thin treatment uses a one dimensional quadratic potential for the V(q) potential. Results obtained by this method are compared with experimental ones and appear to agree very well.

163. KRICK(M.S.) and EVANS(A.E.) The measurements of total delayed-neutron yields as a function of the energy of the neutron inducing fission. Nucl.Sci. & Eng. 47,3; March, 1972; 311-3. The delayed neutron yields from 233U,235U,238U,239Pu and 242 Pu have been measured as a function of the energy of the neutron inducing fission. The measurements extend from .1 to 6.5 MeV for 233U and 235U from 1.6 to 6.5 MeV for 238U for .1 to 1.8MeV for 239 Pu and from .7 to 1.3 MeV for 242 Pu No variation in the yield with energy for any of these isotopes was found to decrease by approxi 30%. The absolute yield for 242Pu was measured for the first time, resulting a value of 0.016 $\pm$0.005 delayed neutron per fission. The average energies of the delayed neutron from 233U 235U, 239Pu and 242 Pu were estimated to be slightly less than 0.5 MeV for fissioning neutron energies below 1.8MeV.

164. KOLOSOV. (N.D.) etc. Sov.At.Energy.32,1;Jan,1972 83-4.

An analysis of versus En dependence is carried out and results are given of yields and kinetic energies of fragments present during U233 and Pu239 neutron fission,measured in the range 0-16 and 0-0.08 MeV, resp. The neutron energy resolution was ± 50 KeV For Pu239, the value was 0.104 for 233 U = 0.102. The En reference value for Pu239 were the reference values for U233 and Pu239 were the thermal fission values of 2.48 and 2.8738 resp. The rather low values are attributed particularly to redistribution of charges between fragments.

165. MATHEWS(C.K) and TOMLINSON(R.H) Cumulative yield of the heavy fragments in the fast neutron neutron fission of 238U (Can.J.Phys. 50,24;Dec 15,1972; 3100-10.

Isotopic abundances of the elements Xenon,Cesium barium. Cerium,neodymium,and Samarium from in the fast neutron fission of 238U have been measured using the mass spectrometric method. These ratios were normalised with respect to each other through isobaric nuclides and isotope dilution to obtained the relative yields of isobaric chains in the heavy mass region. By normalizing the heavy mass yield to 100% the absolute fission yield of 20 chains in the 130-154 mass range were determined.

166. VAN'KOV(AA) and STAVISSKII(Yu.Ya) Measurement of mean number of U235 and Pu239 fission neutrons emitted peract of 24KeV neutron capture. Atomnaya Energies V.19,1; 1965; 41-2P.

The measurements were carried out by a direct method of determination of the difference between the number of absorbed neutrons coming from the source and the number of fission neutrons, by taking advantage of the different moderation length of the two neutron groups.

NEUTRON, FISSION-MEASUREMENT

167. ALBINSSON (H) Measurement of life times and energies on neutron-rich nuclei produced in the fission process J.Phys. (France) 33,8-9; Aug-Sept., 1972; 32 P. (European Conference on Nuclear Physics).

Measurements were made on -radiations emitted from the fragments were slow neutron induced fission of 235U. The time distrib of the radiation can be devided into two parts, a prompt one, with a half life shorten than about .1ns and a delayed one. Studied of prompt rays have been revealed that a few gross structure exist in the time distrib. The yield of prompt photons of half lives of about 20ps was studied as function of the total kinetic energy of the fragments. For near-symmetric fission the yield increases with mass, contrary to the corresponding yield of prompt neutrons. For asymmetric fission on the other hand, the no. of photons decreases with increasing total K. of the fragments.

NEUTRON, FISSION-PENETRABILITY

168. BLOCKI(J) etc. Penetrability of nuclear fission barrier for muonic atoms. Phys.Lett.B.42B, 4; Dec.25, 1972; 415-18.

The nuclear fission penetrability for muonic atoms is calculated as function of excitation energy. The results obtained for 234,236,238U and 240 Pu are compared with the fission of normal atoms.

NEUTRON-IRRADIATION

169. SPIRIDON(C) and CALUSARU (A) Chemical states and thermal annealing of the 131 I 133I and 135I formed by 235U fission during thermal neutron irradiation of uranyl nitrate at room temperature and liquid nitrogen temperature J.Inorg.& Nucl.Chem. (G.B) 35, 3; March, 1973; 713-25.

By means of anion exchange method using KNO3 solutions as eluent, the species IO IO I and I have been separated, after dissolution of uranyl nitrate crystals irradiated with thermal neutron.

NEUTRON-MEASUREMENT

170. BOCKHOFF(K.H.) etc. Neutron total cross-section flucations of 235U in the KeV range.J.Nucl.E nergy. 26,2; Feb, 1972; 91-7.

rRelative neutron total cross section of 235U have been measured in neutron energy range between 10 and 100 KeV with a time of flight resolution of 0.3 mm/m. Strong structure is observed in the total cross-section which is atleast in high resolution fission cross-section measurement. Thus indicating that the latter is at least in part due to the entrance rather than the fission channel. A monte carlo simulation of the total cross section shows that its structure may be fully explained in terms of pure resonance parameter statistic.

171. KRICK(M.S) EVANS(A.E.) The measurement of total delayed neutron yields as function of the energy of the neutron inducing fission. Nucl.Sci.& Eng. 47, 3; March, 1972; 311-8.

Total delayed neutron yield from 233 U, 235U,238, 239Pu and 262 Pu have been measured as a function of the energy of the neutron inducing fission.

NEUTRON-RESOURCES

172. CORVI(F) etc. Spin assignments of 235U neutron resonances and estimate of for J = 3- and 4- levels.

J.Phys.33,8-9, Aug-Sept.,1972; 20 (European Conference on nuclear Physics. Abstracts only. Aix-en-Price , France, 26 June, 1 July 1972)

Since the ground state of 235U has spin and pairty I = 7/2-, the s-wave neutron resonances which doimnate the slow neutron, induced fission of 235U, correspond to levels of 236U with J = 3- and 4-. Knowledge of this spins of a considerable sample of such resonanced is necessary in order to give an estimate of the average fission widths for the two spin states. These T values can be provide a further experimental check of the Bohr hypothesis that the nucleus at the saddle point proceeds to fission through a number of transistion stated of collective nature. It can be available for J = 3- levels and 1 to 2 shown that a maximum of 2 to 3 channels should be available for J = 3- levels and 1 to 2 channels for J = 4-. The corresponding T should then be in the same ratio. In order to assign resonance spins, the authors applied to 235U the low-level population method which already proved very effective for non-fissile nuclei.

NEUTRON-SPECTRUM

173. FIEG(G) Measurements of delayed fission neutron spectra of 235U,238U and 239Pu with proton recoil proportional counters. J.Nucl.Energy, 26,12; Dec, 1972; 585-92.

The delayed fission neutron spectra of 235U,238U and 239Pu were measured for different time intervals after fission with proton recoil proportional counters. These measurements, the spectra of the various time groups were determined .14 MeV neutron and, for 235U, also thermal neutron were used to induced fission where published experimental group spectra were available, comparison with these results were made.

174. KNILLER(H.H.) and ISLAM (M.M.) Prompt fission neutron energy spectrum of 235U at En = .4 MeV J.Phys.(France) 33,8-9; Aug,Sept,1972; 33 p. (European conference on nuclear physics).

The measure the fission neutron energy spectrum of 235U at .4MeV incident neutron energy. The measurements were obtained using nanosecond time-of-flight technique with three detectors.

175. McElory (W.N.) The spectral distribution of neutrons and neutron reaction cross sections in an unreflected uranium .235 critical assembly and the fission neutron spectrum.

Nucl.Sci. & Eng. 48,1; May, 1972; 51-71.

Previously reported inconsitencies between activation detector and n,p scattering/time-of-flight(TOF) measurements of the thermal-neutron-incuded 235U fission spectrum prompted a comparison of such measurements in the core centre and on the surface of a bare 235U assembly, referred to as Godiva. For The present study TOF measurements and multiple foil measurements of the core and surface spectra of the APPA-III Godiva are compared. Comparison of the integral fluxes above specified energies for the two methods show agreement to within 5% at core centre. Results for the fission spectrum are re-analyzed using the same evaluated energy-dependent cross sections as used for Godiva study but with a large number of foil reactions than previously available. A Monte Carlo error analysis Code is used for the assignment of errors for the activation results for the Godiva and fission spectrum studies.

NEUTRON-STRUCTURE

176. JAMES(G.D.) etc Intermediate structure in the neutron induced 235U cross section. Trans.Am.Nucl Soc. 17; Sept; 1973; 495-6 (American Nuclear Society 1973 winter meeting california 11-15 Nov. 1973.

The 235U fission cross section exhibits large fluctuations in the unresolved resonance region. The authors consider whether this phenomena can be explained in terms of the statistical nuclear model, or whether on the contrary, these fluctuations represent departures from it, in localized energy regions, where enhancements of the reaction width occur.

NEUTRON-THERMAL

177. APALIN (VP) etc. Kinetic energy of fragments and energy balance in the fission of U235 by thermal neutrons. Nuclear Phys. V. 71,13; 1965; 546-52 P.

The distribution of the total kinetic energy of additional fragments as a function of their mass ratio was measured with a gas function chamber. The difference between the average kinetic energies in symmetrical fission and the fission in which the heavy fragments is 'magic' is found to be 21 MeV. The maxi-minimum ratio for the yield curve of fragments in symmetrical fission was 500:1 in these measurements.

178. PARSON(R.W.) and SHARMA (H.D.) Nuclear charge distribution in mass chain 131-123 in thermal neutron fission of 235U. J.Inorg.& Nucl.Chem. 30, 10; Oct 1974. 2392-6P. The fractional independent yield of 131-133Te, 133I and 134I in thermal neutron fission of 235U is reported.

179. EFIMOV(V.N.) etc. Nucleon-nucleon T matrix factorization for realistic potentials. Phys.Lett. B.(Netherland) 37B,3; 29 Dec. 1971; 269-71.

The nucleon-nucleon T-matrix off energy shell is factorized with respect to momentum variables for potentials with a hard conc. The expressions derived give a momentum practical possibility of solving numerically the three-nucleon Faddeev equations.

NUCLEAR EXPLOSION

180. ALBERT(R.D), U233 fission cross section measured using a nuclear exposion in space. Phys.Rev.V.142, 3; 18 Feb. 1966; 778-87p.

A high-altitude nuclear explosion in 1962 was used as a neutron source in an experimental to measured the fission cross section of U233 relative to U235 in the 30 eV to 5 MeV energy region. Fission data were telemetered to the ground station at Kanai. The flight experiment path for the neutron time-of-flight experiment was 1280 Km. The U233 fission cross section results indicated average value about 20% lower in the 2 MeV energy region and about 30-40% higher in the 30-500 eV energy region than the average of previously obtained value.

NUCLEAR EXPLOSION-UNDER GROUND

181. FLEISCHER (R.L.) etc. Effect of shock on fission track dating of aptitude and sphere crystals from the Hardhat and Sadan underground nuclear explosions.

J.Geophys.Res. 79, 20; Jan, 1974; 330-42.

Apatitude and sphere crystals from granodiorite exposed to underground nuclear explosions were dated by the fission track method. The effect of shock pressure on the measured track densities and consequently on fission track ages was sought for samples taken from several different positions relative to the detonation point. Shock has not noticeably altered track come angles,

NUCLEAR FISSION-IONS

182. KARAMYAN, (S.A.) Tak'An'(Nguen) and Sharifow(K.N) Energetic balance for nuclean fission with heavyions. Sov.J.Nucl.Phys. 15,3; 1972; 435-43.

The values of the number were measured for reactions of U238,Bi209,Au197 nuclei with accelerated ions C12,)16, Ne22, and Ar 40. Using published data on the K and mass distrib of the fission products the total energetic balance of the above reaction was calculated. The measured number valuer were consistent with energy conservation. The elaborated methods of the energy balance calculations can be used in calculation of number of fission reactions for which there are no experimental data. The energetic balance of a hypothetic spontaneous nuclei fission is considered for 90. It is found that the spontaneous fission mechanism for 84 nuclei should considerably differ from the usual one.

NUCLEAR FISSION-THERMAL

183. GIARJAN (N) etc. Nuclear structure effects in accompahed fission. Rev.Roum. Phys.(Rumania) 18,2; 1973; 151-63.

particles formation probability on the surface of the fissioning system, at different moment of the thermal neutron fission of 235U and spontaneous fission of 252Cf, is computed in the point particle approximation, with in the R-matrix theory. The variation with the channel surface and with the position on the channel surface is given. The results obtained afford, a qualitative explanation of the angular distribution including the existence of polar emission, of the _ particles accompanying the fission process.

184. GUNTHER(H) etc. Fission fragment change distrib in thermal-neutron induced fission of 239 Pu and 235U. Nucl.Phys.A. A 196, 2; Nov.27,1972; 401-11.

Fission fragment charge distrib of heavy fragments were investigated for fragment masses 131 A 140 in the reaction 239 Pu (nth,f) and 235U (nth,f) This was done by a correlated observation of tracks and fission fragment tracks in nuclear emulsions for fission fragments separated with respect to mass and kinetic energy by recoil mass spectrograph. The average nuclear charges are almost identical for both fissioning nuclei in the fragment mass range investigated specifically for both systems the yields of the doubly magic 50 132 Sn82 appear to be enhanced. Both observations again support to hypothesis that in low-excitation fission of the actívides the nuclear structure of the heavy fragment play a predominant role.

185. FLUSS, (J.M.) DUDEY(N.D) and MALEWICKI(R.L.) Tritium and particles yields in fast and thermal neutron fission of 235U. Phys.Rev.C. 6,6; Dec. 1972; 2252-9.

The tritium yields per fission of 236U are reported for the reaction 235U+n from thermal energies to 700 KeV In addition the corresponding particles yields an energy spectra are reported above neutron energies of 170 KeV. An increase of a factor of 2.3 to 2.4 in the tritium yields over its thermal value of 0.85 ± 0.09 x 10-4 tritons per fission is observed. No similar charge is observed for the particles yields.

NUCLEAR-FUEL

186. D'ANGELO (A) etc. 235U compact Cu-reflected TAPIRO reactor integral experiment results and a check of some high-energy ENDF/B-III data. Trans.Am.Nucl.Soc. 17; Sept, 1973; 448-9.(Am. Nuclear Society 1973 winter meeting california, 11-15 Nov. 1973).

The fast source TAPRIO reactor a small compact 235U metal and Cu-reflected system, was used for reactor physics measurements; in particular,central reactivity and fission are ratios. Moreover, an equivalent snehrical model of the reactor was carefully defined for nuclear data testing purpose.

NUCLEAR, INSTRUMENTS

187. LUIZOV (A.V.) and Fedorova, (N.S.) An information theory criterion for evaluating the quality of telescopic instruments Sov.J.Opt.Technol. 38,6; June, 1971; 331-4.

Information theory criteria for the quality of telescopi instruments are indorduced, and several binoculars and human eyes are evaluated on the basis of these criteria.

NUCLEAR-REACTION

188. CHAWLA (R) Improvements in the prediction of reactivity and reaction rate ratios for U lattice J.Nucl.Energy 27,11; Nov. 1973, 797-80.

Evidence from a broad range of clean, bench mark experiments has been used to assess the performance of best available theoretical method and differential data for predicting integral thermal reactor properties such as reactivity and reaction rate ratios. It is shown that for imporving the consistency of calculated integral parameters for D2o, H2O and graphite moderated, uranium data are desirable. Along with changes in moderators scattering cross-section, 238U resonance data and the 235U fission energy spectrum, some modification of 235U thermal data have been made which lies within the experimental uncertainties of differential measurements.

189. PORILE (NT) Analysis of thick target recoil studies of high-energy nuclear reaction. Phys. Rev. 185,4; 1969; 1371-7.

The effect of broad velocity distribution on the vector-model analysis of average projected ranges obtained in thick-target experimental has been explored. The Monte Carlo technique was used to Construct. laboratory velocity distributions on the basis of impact (II) and breakup (V) velocity distributions inferred from differential recoil studies. A range velocity relation for fission products in U was constructed and use to convert the laboratory velocities to average projected ranges.

190. SCHRODE (B) etc. Photo induced nuclear reactions above 1 GeV IV Mass distribution in the 6.00 GeV bremsstra. hlung-induced fission of natural U. Nucl. Phys.A. 197; 1; Dec. 11, 1972; 88-96.

The mass distrib in the 6.00 GeV bremsstrahlung-induced fission of natural U has been analysed. The measured yields are shown to correspond to at least 90% of the chein yields. The results are compared with other experiments. The mass distrib curve has been decomposed into two distributions, one symmetric and one symmetri- Finally the peak-to-valley ratio obtained is compared with the results above 1GeV it is deduced that the total fission cross section for 238 U decreases rapidly with energy.

NUCLEAR, REACTOR-HYBRID

191. HASSE, (R.M.) A two nuclei shell model with pairing and its applications to the session region Proceedings of international conference on Nucl. Phys. Vol.1 Germany, 27 Aug-1 Sept, 1973.

A two-nuclei shell model is proposed in order to calculate the interaction energy of the fragments close to each other. The result for the symmetric fission process 236U 118 Pd + 118 Pd are given.

NUCLEAR,REACTOR-HYBRID

192. KOLESNICHENKO(YA.I.) and PEZINK,(S.N.) D-T plasma as a source of neutrons for the combustion of Uranium - 238.

Nucl.Fusion, 14,1; January, 1974; 114-16.

The Principles of operation of a nuclear hybrid nuclear reactor- a system based on the simultaneous occurrence of interdepednet thermonuclear and nuclear fission reactions-are discussed. It is shown that the fast-fission blanket is of a reasonable size and the plasma does not have to meet such regions requirements as in the case of a thermo-nuclear reactor.

NUCLIDES

193. CUMMING, (J.B.) and BACHMANN,(K.) Recoil properties of rare earth nuclides produced by the interaction of 28-GeV protons with U and gold Phys.Rev.C, 6,4; Oct, 1972; 1362-71.

The thick-target-thicks-catcher technique was used to determine the recoil properties of some rare earth nuclides produced by the interaction of 28 GeV proton with U and Gold. Mean momenta derived from this and other experiments are discussed in terms of fission and spallation like processes.

PARAMETERS

194. SCHULTHEIS (H) and SCHULTHESIS (R) Fragment stiffness-parameters Cr at Scission. Phys.Lett.B.52B,4.28Oct 1974 389-91 P.

The fragment deformation at secession and stiffness parameters Cr are calculated for the fission of 236U and 252Cf The results show that in both compound nuclei the stability against axial asymmetric deformation is determined by fragments shell effects in the -values.

PHOTOFISSION

195. ANDERSON(G) Photo-induced nuclear reactions above 1 GeV I. Experimental. Nucl.Phys.A. 197,1; Dec, 1972; 44-70.

The yields of the reactions 12C $(r,n)^{11}C$, $^{27}Al(r,\ \ )^{27}$ Mg, 27Al(,2pn)24 Na, 127I (,ypxn) and 197 Au(r,Xn) have been measured in the energy range 1-7 GeV by the activation method without chemical separation. The yieldsand the F/B ratios in the plotofission of An and Pb have been measured by glass-plate detectors. From the yields the cross sections have been deduced. Further, the mass distribution from 238 Photofission was measured. The results fit well to earlier measurements below 1 GeV. The analysis and discussion of the spallation and fission results are given in a series of consecutive papers.

196. CARBONARA(F) etc. Photofission of U and Th between 300 and 1000 MeV. Nuclear Phys. V.73,2; 1965; 395-97P

Loaded nuclear emulsions have been exposed to the bremsstrah lung beam of the Frascati 1 GeV electron synchrotron to measure natural uranium and thorium fission cross-section in the energy range 3000-1000MeV The cross-sections 'Per photon' are constant within the experimental errors, and amount to 67 + 7 and 37 + 4 mb, for U and Th, respectively.

197. DEBRUS(J) etc. Highenergy Photofission of gold and uranium.

Nucl.Phys.A. 197, 1; Dec, 1972; 163-76.

Breinsstrahlung induced photofission of 197 Au and 238U has been measured for energies E max = 0.8 to 2.7 GeV using catcher foil techniques. The mass distributions of the fission fragments of uranium were measured as a function of the maximum brensstrahlung energy. The peak-to-valley and forward backgrod ratios have been determined for 238U.

198. FORD, W.E. The testing of 238U photon production data from ENDF/B materials 58, 702 and 4187.

Trans. Am.Nucl.Soc. 17; Sept., 1973; 545-6.

Photon production data from three sets of 238 U ENDF/B data, MATs 58'd and 702[2,b] and 4187, mod 1.[3,c] were tested by using the data to calculate secondary gamma-ray pulse-height spectra (SGRPHS) that could be compared with measured spectra.

199. HAUPT, J. Experimental results on the dynamic polarisation in a solid by variation of temperature.

Z.Naturforsch. A 282A 1; Jan, 1973; 98-104.

A description of the apparatus for a new dynamic polarization effect by variation of temperature, and the experimental results obtained, are presented. A temp Jung produces a very large enhancement of the dipoler signal in solid r-picolene due to the diploar couplings between the protons of the CH3- groups and the modes of the CH3-rotator with the crystal phonons. A simple phenomenological model for the interpretat-tion of the experimental data is introduced. With in the experimental errors agreement between model and data is obtained. From the shape of the measured polarization curves a diploar polarization time Tp and the diploar relaxation time Td are determined. For the maxima of the polarization at different temp. Jumps a curve dependent only on the temperature is constructed, which together with Tp and Td characterise, completely the dynamic polarization behaviour

200. KHAN, A.M. and KNOWLES, J.W., Photofission of 232Th, 238U and 235U near threshold using a variable energy beam of gamm-rays.

Nucl.Phys.A. 179, 2; Jan, 1972; 333-52-

Photofission cross sections of 232Th,238U and 235U between 5 and 8.3 MeV have been measured with 1.0 and 1.7 mg-cm-2 targets of thorium, natural uranium and enriched uranium (235U, 46 and 89%) coated on walls of cylindrical ion chambers. The beam of incident -radition of variable energy has a spread of 4 to 5%. Pronounced peaks are observed in 232 Th at 6.4 MeV, 650 KeV wide and in 238U at 5.2 MeV, 200 KeV wide. No well defined peaks are observed in the 235U photofission cross-section. Photofission t ransmission factors of 223 Th and 238U are derived.

201. MAFRA, O.Y. KUNIYOSHI, S.K. and GOLDEMBERG,J. Intermediate structure in the photoneutron and photofission cross section in 238U and 232Th. Nucl.Phys.A. A 186, 1; May, 1972, 110-26.

The (r,f) and (r,n) cross section in 238U and 232Th and the ratio were measured with monocromoatic -rays, of energies from 5.43 to 9.0 MeV. The competition between the two processes and the implication of the cross-section behaviour are discussed.

202. PETRZHAK, K.A. TEPLYKH, V.F.PAN'YAN,M.G. and DEMIN, V.A. Relative yields of xenon isotopes in photofission of U 238 Soc.J.Nucl.Phys.14,5; 1971; 950-2.

Relative yields of the isotopes Xe 131, Xe 132, Xe 134 and Xe 136 are measured for the photo-fission of U239 and at the maximal Bremsstrahlung energies of 15 and 25 MeV A highly sensitive mass-spectrometer was used. The fine-structure peak of the fragment yield curve is established to be a A = 134 for both the energies. The results of the measurements are compared with the experimental data by other authors obtained for spontaneous fission of the saine nucleus.

203. REICHSTEIN (I) and MALIK, F.B, The external fission potential energy surface of 240Pu and the mass distrib. Proceedings of the international conference on Nucl.Phys. Vol.1 Germany, 27 Aug-1 Sept. 1973. 592 P.

Starting from an energy density functional for a variable density distribution derived by Brueckner et al (1968) from an extended version of the Brueckner, Hartree-Fock Theory of nuclear matter, the authors have calculated the potential energy surface between the two decaying fragments of 240Pu.

204. SWINDLE (D) Mass distribution of fission products following photofission of U238 Nucl.Sci.& Engg 52, 4; Dec. 1973. 466-73.

The mass yield distrib of fission products following photofission of 238U using bremsstrahlung energies of 24,24 and 25 MeV. were measured vy radiochemically isolating the fission products belonging to 24 mass chains. The absolute activities of these nuclide were determined by and counting techniques and the cumulative fission yields were calculated relative to 140 Ba The peak-to-valley ratio was found to be effective constant, thus, the average photon-energy-inducing fission is essentially equal for all three energies studied in this work.

205. VEYSSIERE(A) etc. A study of photofission and photoneutron processes in the gaint dipole resonance of 232Th,238U and 237 Np. Nucl.Phys.A. A199, 1; Jan 8, 1973; 45-64.

Partial photoneutron cross-sections (r,n) and (r,2n) together with photofission cross-section (r,F) of 232Th, 238U and 237 Np were measured using a monochrometic photon beam in the giant -resonance region. A new data analysing technqiou has been applied so as to make a direct separate and simulatneous evaluation of the above cross-section possible. Thresholds, absolute cross-soction values, lorentz line parameter intrinsic quadrupole moments and integrated cross-section are evaluated. A special study of the competition T /T between the fission and neutron exit channels is also presented. Finally a determination and the 'non-statsitical' neutron contribution and an evaluation of the nuclear temperature of 237U are also given.

PHOTOFISSION-DISTRIBUTION

206. DEMEKHINA(N.A) Anisotropy in angular distribution of fragments of photofission at high energies.

Yad.Fiz.16,5; 1972;911-15 In Russian. English translation in :Sov.J.Nucl.Phys.(Received: Nov.1972).

Fragment angular distributions of U 238 Bi209,Au197 and 181 fission have been measured with micadetectoos for the energy range E max from 600 to 5100 MeV. It is shown, that fragment angular distributions of U238 fission are isotropic within 3%, while in the case of Bi209,Au197 and Ta181 nuclei an anistropy of about 10-20% is observed with primary emission of fragments in the photon beam direction.

REACTOR-ANALYSIS

207. COHALAN, J.E. and OH, K.O. Delayed neutron data for fast reactor analysis. Nucl.Sci.& Eng. 50,3; March, 1973; 208-15.

The delayed neutron precursor decay curves which result from a pulse of fission of the isotopes 233U, 235U, 238U, 232Th, 239Pu, 240Pu, 241, Pu and 242Pu are consistently fit, yo a single set of six isotopes indpendent decay constants. The newly filted data are tested by the analysis of a typical first reactor transient. The analysis shows that the utilizing of a new data in comparison to the use of orignal data results in an insignificantly small elevistion, while permitting a considerable reduction of for calculation effort. The new technique developed/the fittings is shown to preserve important integral kinetics parameters.

REACTOR-FUEL

208. DUDEY, (N.D) etc. Fission product rate measurements and yields. Trans. Am.Nucl.Soc.17; Sept.1973;518

The authors evaluate the foil technique for measuring fission rates of 235U, 238U and 239 Pu, by performing measurements in neutron environments (SSTR) in which fission chambers and solid State track recorders(SSTR) may also be utilized.

209. GRUNDL (J.A), DUDEY,(N.D) and POPEK(R.J.) Measurements of absolute fission rates. Trans.Am.Nucl. Soc. 17; Sept, 1973; 516-17.

The authors present results for absolute fission fragment emission rates from 239Pu, 235U, 238U and 237Np exposed to the fast-neutron fluxes of the central spectrum of the CRRMF Reactor at ANC.

REACTORS

210. ABRAHAMSON, D .E. Is nuclear fission an acceptable means of producgin energy? Trans.An.Nucl.Soc. 17; Sept, 1973; 410-11 (American Nucl. Society 1973 winter Meeting, California, 11-15 Nov.1973).

The author discusses the environmental hazards and Socio-economic factors associated with nuclear reactor power production from the 235U/239Pu cycle.

REACTORS

211. PAZIRANDEH,(A) and BESANT,(C.B.) Measurement of fission ratio in Zero power reactors. J.Br.Nucl. Energy.Soc. 11,4;Oct,1972; 377-82

Fission rate ratios of 238U relative to 235U have been measured in the uni of London reactor CONSORT by detecting the fission product - activity from irradiated U foils. It was necessary to utilise a time-dependent calibration factor to relate the -activity ratio to the true fission ratio. The technique has been used by other laboratories for measurements in fast reactors and so the neutron spectrum dependence of parameters, such as the time-dependent calibration factor has been examined.

212. PRAKASH(S) etc. Kinetic energy release in reactor neutron induced fission of 232 Th. J.Inorg.Nuclear Chem.31,5; 1969; 1217-24.

Ranges of eleven fission products produced in the reactor neutron fission of thorium-232 were determined radiochemically using the thick-target-thick catcher technique. Kinetic energies of the fission fragments were calculated from the ranges and the kinetic energy deficit in the symmetric fission region was estimated to be 28.5 MeV

SHIELDING-EFFECTS

213. CULLEN,(D.E.) and PLECHATY(E.F) Calculation of resonance self shielding in 239 Pu and 235U. Trans.Am. Nucl.Soc. 17; Sept. 1973; 490-1.

The authors examine self shielding effects in the fission of 239Pu and 235U after transmission of neutrons through plates of these materials.

SPECTRACOPY

214. CAMBIAGHI,(M) etc Experimental results concerning long-range light particles and fragments in the ternary fission of 233U,235U,239Pu and 252Cf. Nuovocimento A 11 A,See 2,3; 10 Oct,1972; 716-24.

In present paper the yields and energy spectra of 6He particles from the thermal fission of 233U,235U and 239 Pu are reported. Data concerning 3H emission in the 235U fission are given too.

SPECTROSCOPY

215. GREEN (L) MITCHELL, (J.A.) and STEIN, (N.M). The 233U fission neutron spectrum from .8 to 10 MeV. Nucl. Sci. & Eng. 52, 3; Nov, 1973; 406-12.

The 233 U fission neutron spectrum has been measured by pulsed beam time-off flightly-technique from .8 to 10 MeV Above 2MeV, the data were found, within statics, to be adequately represented by either the model in the ENDF/B-III file or a best fit Maxwellian distrib with nearly the same average energy. At lower energy, the data appears to follow ENDF/B representation some what more closely. The fit of a Maxwellia distribution to the 233 U data yielded an average temperature parameter of 1.3 ± 0.02 MeV, where the error include both statistical and systematic uncertainties. A similar fit of data taken for a 235 U sample yielded a temperature parameter of 1.31 ± .03 MeV however, the best estimated difference in temp is 16 ± 6 KeV.

216. NISHIHARA (H) and OHTA (M) Simulation of fast-reactor spectra. Applications to calculations of reactivity effects and of fission to (n,2n)-reaction ratios in fast reactors. J.Nucl. Sci. & Technolo. 10,7; 1973, 402-10.

To simulate fast-reactor spectra, a simple shape function f(U; Um,) with spectral parameters Um and B has been derived by expanding the gross shape of the spectrum into a series of Hermite function . The parameters are determined by the moment method. It is shown through some sample problems that the shape function is applicable to both Core and blanket.

217. PARSONS (R.W.) and SHARMA (H.D.) A simple method for the determination of independent yields in fission with a Ge (Li) detector. Radiochem & Radioanal., Lett. 15, 4-5; Nov. 20, 1973; 335-45.

A method for determination of independent yield in fission is outlined. A high resolution Ge( ) detector is used for recording r-ray spectra of chemically separated elements from fission-products mixture. The independent yields are evaluated such that r-ray intensity data of nuclides, the efficiency of the detector and geometry factors are not needed.

218. VOROBIEV (AA) etc. Light nuclei from 233 U neutron fission Phys.Letters. 30B, 5; 1969; 322-4.

The energy spectra and the relative intensities of 2H, 3H, 4He, 8He 7Li,8Li,9Li, 9Be and 10Be from 233 U neutron fission have been measured with a mass spectrometer measuring time of flight and energy. The upper limits of the yields of 3He,9Li and 7Be have been determined the yields proved to be low as compared to the intensities of the other identified particles.

219. VOROBYOV (A.A) etc Light nuclei from ternary fission. Proceedings of the international conference on Nuclear Physics, Vol.1 Germany, 27 Aug-1Sept. 1973,716 P.

Enery spectra and yields of the light nuclei with Z?? produced in neutron induced fission of 237U,235U, 239Pu, 242m have been determined by using magnetic mass-spectrometer with energy, time of flight and measurements. The mass and charge resolution of the spectrometer was sufficient for an isotopic analysis of the particles with Z 15. Experiments were performed using a reactor neutron flux of 10^{13} neutron/sec cm^2 and target thicknesses of .1 to 5 mg/cm2

SPECTROSCOPY-CHEMICAL

220. ESTERLUND,(R.N.)etc Reaction of U with 9.6MeV/nucleon copper ions. Proceedings of International Conference on Nuclear Physics. Vol. 1 Munich, Germany, 27 Aug-1 Sept. 1973 554P.

A thick U foil was irradiated with 10^{15} copper ions 9.6 MeV/nucleon for a period of 27 hours. A complex chemical separation was performed on the target resulting in six sources all of which were assayed for spontaneous -fission activity, and in addition, alpha-and r-spectrum were taken.

SPECTROSCOPY-EQUILIBRIUM

221. CALBOREANU (A) etc. Delayed gamma rays from fission induced by 13.3 MeV protons on 230Th-235 U and natural Ur. Rev. Roum.Phys.19,6; 1974. 629-41P.

The delayed gamma rays emitted by fission products, with half lives from minutes to tens of hours, in

SPECTROSCOPY-GAMMARY

222. CALBOREANU(A) etc. Delayed rays from fission induced by 13.3 Mev proton on 232Th,235U and natural Uranium: Rev.Roum.Phys. 19,6; 1974;629-41P.

The delayed rays emitted by fission products, with half-lives from minutes to tens of hours, in proton induced fission on 232 Th 235 U and natural Uranium have been studied using G.e(Li) spectrometry .23r-rays belonging to 17 isotronic chains have been identified from the r spectra corresponding to the three fission able targets irradiated and measured in identical condition 12 r lines have been selected and their relative intensities compared. During the temporal vealution of a certain specified r-ray, its real intensity may be more or less disorted by other r-rays with close energies, but different half-lives. In order to establish the appropriate moment of measurement i.e. the time internal when the contaminating contribution is minimum, a method of optimization is outlined.

223. FREHANT (J) SHACKLETON (D) and TROCHON (J) Prompt neutron and r-ray yields in fission induced in 239Pu and 235 U by resonance neutrons: existence of the (n,rf) reaction. Proceedings of the International Conference on Nulc. Phys.Vol.1 Germany 27 Aug.I Sept 1973; 606 P A measurement of the mean numbers of prompt neutrons, and of Er the mean total prompt r-ray energy has recently been carried out at Saclay for the fission of 235U and 239 Pu induced by S-wave resonance energy neutron. The Saclay 60 Mev eletrcon linear accelerator was used a pulsed neutron source. A multiplate ionization chamber was used in conjunction with a 250 1 Gd-loaded scintillation detector. The Prompt scintillator pulses were used to measure Er.

224. GERMAN(E) etc. Application of GeLi detector to the measurement of U-238 fission yields for 14.4 Mev neutron. Neitro-nnaya Fizika. (All union conference on Nucle .Phys.Pt. III,Kiev.USSR, 28 May - 1 June 1973.

Absolute cumulative yield for 17 fission fragment of 14.4 Mev neutron indufed fission of U-238 were determined using a Geli gamma spectrometer and a thick U target without any chemical separation or applying recoil effect.

The results are compared with other GeLi and radiochemical data. The accuracy of the yield determination depends mainly on the knowledge of gamma intensities used in the calculation.

225. YUROVA (LN) BUSHEV(AV) and KOZLIN(AF) Yield of some fragment from the fission of U238 by neutron with a reactor spectra Neitronnaya Fizkika (All Union Conference Neutron Phys.) Pt. III Kiev.USSR, 20 May-1 June 1973. 315-22 P.

The probability of formation of various products in U238 fission by neutron in the IRT-2000 reactor is determined. The measurement of spectra for fission product were carried at using a Ge(Li) spectrometer. Absolute yields of U238 fission products were carried at calculated by the yields values if corresponding products in the process of fissioning of U235 by thermal neutron in the same reaction, the no. of fission in the sample was evaluated according to the intensity of the radiation of the fragment.

226. ZAPPE(D) and SCHURICHT (V) Radio Chem & Radional. Lett. 15,3; Oct 20, 1973; 167-85.

The methods to measure the r-spectra of fission products are briefly reviewed and the methods of calculation of the spectra are described Results are compared with those of their authors on-fission-products produced by the fission of 235U with thermal neutrons. After about a few days of decay high-energetic components appear in the spectra of the fission products, which have not been reported so far. In most of the cases the spectra of the different type of fission differ from each other in lesser extent that the spectra of the same type of fission reported by various authors.

SPECTROSCOPY-NEUTRON

227. ABRAMSON(D) ect Neitronnaya Fisika (All Union Conference on Neutron Phys) Pt. III Kiev USSR, 28 May-1 June 1973 46-55P

Measurements have been made of fission energy spectra induced by fast neutron on 235U and 239 Pu with a system of four detectors. The technique of time of flight and pulse shape discrimination are used. The detectors efficiency is measured with respect to a calibrate sensitive long counter. The shape of the fission neutron spectra as well represented, in the range 0.7-5 MeV by the Maxwellian distribution with a temperature of 1.30 Mev for 235U and 1.37 Mev for 239 Pu.

228. DEBEAUVAIS(M) etc. Practical neutron spectrometry with visual ionographic detectors. RC Acad.Naz Lincei 45, 5; 1968; 259-60.

A spectrometer for 0 to 20 MeV neutron is made with the aid of visual solid detectors. The following reaction are used (1) Fission reaction on natural and enriched uranium with and without cadmium, neptrium and thorium targets for 0 to 10 MeV neutron (ii) (nd) reaction on beryllium, carbon and oxygen targets for 3 to 20 MeV neutron.

SPECTROSCOPY-X RAY

229. ANDERT (K) Interactions of the negative muons with fissile elements. Proceedinfs of the international conference on NuclPhys Vol.1 Germany, 27 Aug-1 Sept. 1973-609 P.

The X-ray spectra of the muonic transition in Pb and 238 U have been measured in exactly the same geometric condition. The X-rays have been detected by the true-coaxial Ge(Li) detectorof 41 CCm volume in coincidence with the mu-capture in the target defined by the conventional method of the 1234 telescope The interent tune resolution was 2 = 11 nsec.

230. BALESTRINI(SJ) and FORMAN,(L) INDEPENDENT fission yields for Rb and Cs from 238 U induced by fission spectrum neutron. Phys. Res.C.10,5, Nov.1974, 1872-9 p.

The on-line fission was measured using by a mass spectrograph equipped with a modified Bernas type surface ionization source placed near a nuclear brust reactor Independent yield of most of the isotope 89-97 Rb and 138-146 Cs was obtained using fractional independent and chain yields deduced from recent cumulative Kr and Xe measurement. The results are fitted by a theoretical model whose parameters, including change deviation and mean square isobanic deviation, are obtained The fractional indpendent yield are lower by (20 ± 10)% for both denotes the mean value showing a odd even Z effect.

231. REDDINGUIS(E,R)etc Spin of low energy neutron resonances in 235U Nucl.Phys.A. A 218, 1; 7 Jan 1974, 84-94.

The spin of 15 resonances in the 235U slow neutron cross section lying in the neutron energy range between .1 and 15 eV were determined by measuring the transmission of polarised mono energetic neutron through a target in which the 235 U nuclei were polarised The magnitude moment of 235U is concluded to be negative.

THERMAL CROSS-SECTION

232. DERUYTTER(A.J.) SPAEPEN,(J) and PELFER(P) The account fission cross-section of 235U from 0.002 to 0.15 eV and its reference value at 2200 m/s. J.Nucl.Energy.27,9; Sept. 1973; 645-76

A slow chopper at BR2 reactor was used simultaneous recordings of pulse-height and time-of-flight spectra of successively compared 235U F4-layers and standard elemental born-layers were made. The detection of 10 B(n,α) L2 and 235U(n,f) reaction fragments is made with a surface-barrier detector. The absolute 10B contents were determined. The relative 10B contents of the standard born-foils were checked by their neutron induced reaction rates in the geometry of the fission experiment. The amount of uranium on the fissible foil is determined by precise low geometry counting.

THERMAL NERGY-NEUTRON

233. SARKAR(R) and CHATTERJEE(A) Excitation and kinetic energies of prompt fission fragments. Phys.Letters.30B 5; 1969; 313-16.

Excitation and kinetic energies of prompt fragments from the thermal neutron induced fission of 233U and spontaneous fission of 252 Cf are estimated by using a renormalised gas model and the potential energy surface concept. The predictions agree fairly well with experiments.

THERMAL FISSION

234. ARMBRUSTER(P) LABUS (H), and REICHELT(K)
Investigation on the primary spins of the 235U fission fragments. Z.Naturforsch. A 26a, 3; March, 1971; 512-22.

The prompt radiation emitted in 235U thermal fission has been investigated in the multiparameter experiment yield, time distribution, energy spectrum and nuclear anisotropy of the emission have been measured, specially yield and anisotropy as a function of fragment mass and -energy. The mass depednce of the primary spins of the fragments can be deduced from these measurements. A value of 7th for the average primary spin and an increase of the primary spins within each fission product group is obtained. This dependence is explained within an adiabatic model of scission due to the mass dependence of the deformation of fragments.

235. BRIDWELL(L), WEHRING(BW) and WYMAN(ME) Time delayed in K X-ray emission during thermal fission of U235. Appl.Phys.Letters. V7,6; 15 Sept.1965;161-3P

The time spectrum of X-rays resulting from internal conversion from light and heavy fission fragments was obtained using a detector which had both time and energy resolution. Thermal fission of U235 was used and gave X-ray peaks at 16 KeV for light fragments and at 32 KeV from heavy fragments.

236. NADKARNI(O.M) Energy and angular distributions of long range charged particles in thermal fission of U235. Nuclear physics and solid state physics symposium abst only. Bombay 6-4 Feb. 1972 1pp.

It was found that for the total long range charged particles (LRCP) energy range the assumed Giassion shape for the angular correlation function is only valid for the angular region of ± 50 about the fission axis.

THERMAL - NEUTRON

237. ANDREEV (V.N.) NEDOPEKIN (VG) and ROGOV(V.I.)
Emission of helium nuclei in the fragment directions at fission of U235 induced by thermal neutrons. J.Nucl Phys. 18,5; 1973; 976-9.

Fission 235U induced by thermal neutrons with simultaneous emission of He nuclei under angles close to 0 resulted to the fission axis. was investigated The energy spectrum of He4 nuclei emitted in the direction of fragments is measured as well as the fragment energy spectrum. The total yield of He4 in the energy range 7-28 MeV was (5.7 ± .3) 10-3 (N sterad)-1, where N tr is the -particle yield from the triple fission in the same energy range. The upper bound for the He6 yield in the energy range 9-33 MeV was found to be 10-4 (N tr sterad)-1.

238. BOGDANOV (V.G.) etc. On the question of the mass distrib of the LRP fission products. Sov.J.Nucl.Phys. 15,2, 1972; 209-12.

The value of a coefficient K which takes into account the particles recoil effect at the construction with Elml = KE hmh formula of the LRP-fission products mass distribution is calculated for different fragment mass ratios of U235 LRP fission by thermal neutron and U238 by fast neutron.

239. GAGGELER (H) and VON GUNTEN(HR) Independent fractional yield of 150Pm in the splitting of 233U, 235U, and 239Pu by thermal neutrons. Helv.Phys.Acta. 46,4, 1 Dec 1973;445 (Swiss Physical Society Meeting,Switzerland 4-5 May 1973)

After chemical separation, the 150Pm content of 233U 235U and 239Pu was determined by gamma spectra scopy and its activity was compared with that of 151 Pm The most probable charge value, known as the Zp-value was evaluated for fission fragments with mass 150 assuming a gaussian charge distribution with equally .59 ± 0.06 The obtained Zp-value were compared with the general charge dispersion curves of fissioning nuclei.

240. MUSTAFA(MG) and SCHMITT(UW) DIPOLE excitation in fission fragments. Nucl.Phys.A 178, 1; Dec, 1971; 9-16.

Dipole excitation in fission fragments at the scission point have been studied in a classical model. These excitations correspond to a density fluctuation caused by the Coulomb repulsion by the fragments. A simple two spere approximation to the scission configuration is used for these studies. The dipole density distrib is obtained from a hydrodynamics picture of the fragment nucle ar and the diploe amplitude parameter are fixed by minimizing the total potential energy at the scission poin Calculation have been made for the symmetric and asymmetric scission configurations corresponding to the fission of 235 U by thermal neutron. The dipole excitation is found to be about .5 MeV in one fragment and at the same time the total energy is lowered by 1 Mev from its value calculated with a uniform density distrib.

241. WIECE(LH), THROUTNER (DE) and FERGUSON(RL) Independent yields of 95Zr from thermal-neutron fission of 235U and 233U Phys.Rev.C. 1,1; 1970; 312-15.

Indepdent fission yields of a5Zr from thermal neutron fission of 235 U and 233U have been determined to be .004 + .002 and .036 + .006, respectively. From the values obtained, together with previously measured yields the width of the charge dispersion for mass as fission product in of the normal. Gaussian curve. An upper limit of .56 for in the case of mass.95 products from 233U fission indicates that charge dispersion in this system is similar to that for 235 U.

242. OKAZAKI (A), WALKER (WI) and BIGHAN (CB) The ratio of the direct to the cumulative yield of 135Xe in the thermal neutron fission of 233U, 235U 239Pu and 241 Pu Canad.J.Phys. V 44, 1; 1966; 237-46P

The ratio of the direct to cumulative yields of 135Xe produced in thermal neutron fission has been determined by measuring the growth and decay of this nuclide in irradiated 233U, 235U, 239Pu and 241Pu. After a short irradiation in a low neutron flux, the amount of 135Xe increases and reaches a maximum at about 11 hours after the end of the irradiation. The direct yield of 135Xe modifies the time this maximum is reached.

243. PLEASONTON,(F), Prompt r-rays emitted in the thermal neutron induced fission of 233U and 239Pu. Nucl.Phys.A. a213, 2; Octo,15,1973; 413-25.

The average no and average energy of r-rays emitted within 5 nses after fission have been determined as function of fragment mass and as function of total K. They were obtained from a four-parameter experiment that recorded even-by-event, correlated of r-rays and of fission-fragment paris, and the time relative to the fission at what a r-rays was detected.

244. POPEKO (LA)etc On spontaneous fission U236 isomer excited when capturing thermal neutron. Sov.J.Nucl. Phys. 17,2; 1973; 234-41.

Porbability of production of spontaneously fissioning U 236m isomor, when capturing thermal neutron by U235 and further cascade transition has experimentally been studied. Delayed coincidence of fission fragments with conversion electrons, characteristic roentgen radiation of K and L series of U and soft r-radiation with energy to 20-200 KeV,were measured. Having analyse the measurement results and assuming that the value of half-life period for spontaneous fissioning isomer lies within 50-100 usec, one has obtained the yield of roentgen K and L radiation not to be high, than 2 x 10-5 quantes/fission, one can predict approximately with the same accuracy, an absence of any -line with energies less than 200 KeV which are pried to isomer fission. The obtained data are being analysed in the frame work of the hypothesis on double peak barrier.

245. REISDORF (W) Fission fragments K x-ray emission and nuclear charge distrib for thermal neutron fission of 233U,235, 239 Pu and spontaneous. fission of 252Cf Nucl.Phys.A. A177,2; Dec. 1971; 337-78

The emission of K x-rays by fission fragments with in n sec after fission has been studied as a function of fragment mass and nuclear charge for thermal neutron induced fission of 233U, 239Pu and spontaneous fission of 252Cf.

246. RUDDY(F.H) and ALEXANDER(J.M.) Long-range fragments from fission of U 236.Phys.Rev.C. 5,2; Feb. 1972; 543-51.

A search for long-range fission products has been made using mica track detectors. Fission of U235 was induced by thermal neutron and He gas was employed as the principal stopping material. Limits are reported for the yield of products with range greater than 20 cm He (25°C, etc).

247. SLOAN(W.R) and WOODRUFF(G.L.) Spectrum of delayed neutrons from the thermal-neutron fission of U235. Nucl. Sci & Engg. 55,1. Sept. 874.28-40P.

Measurements of the spectra of delayed neutrons from the thermal fission of 235U are reported over the energy range 30 to 1500 Kev. The resolution is sufficient to identify the location of peaks in the spectra. Spectra for three different counts-irradiation cycle are reported with the shortest representing a near equilibrium spectrum for delayed neutrons from 235U.

Comparision with existing data show relatively good agreement to the spectral peaks. A correction for the shield of the detector is introduced and applied to the current and previous work with reasonable results. In general the new spectra are softer than previously reported and shew more detailed structure.

2248. UMEZAWA,(H) Independent isomeric yield ratio of 148 Pm in the thermal-neutron induced fission of 233U. J.Inorg. & Nucl.Chem. (G.B.) 35, 2; Feb, 1973; 353-9.

Fractional independent yields of 41.3-d 148m Pm(6-) and 5.37-d 148g Pm (1-) have been determined in the thermal neutron induced fission of 233U by radiochemical technique calculation based on a statistical theory of the spin distribution of the primary fragment has been made for the isomer ratio. A value of mean angular momentum of the primary fragment, J = 8.3 2.0, was obtained by comparing the experimental isomer ratio, m(m + Og) = 0.80 ± 0.06; with the calculated values. The magnitude of the fragment angular momentum agreed well with a predicted value resulting from calculation based on the statistical model using the fragment excitation energy which has been estimated from the experimental data, of the prompt neutron and T-ray emission.

VIBRATIONS-CHARGE

249. KOLUN(R.) MUSTAFA (M.G.) and SCHMITT(H.W.) Calculation of charge vibration in fission with the structinsky shell correction. Nucl.Phys.A. A 222,2; April, 1974; 252-68

The strutinsky shell correction method has been applied to the two spheriod model to study charge vibrations in fission. The investigation is carried out by calculating the potential energy surface with respect to three degrees of freedom; charge vibration from the uniform value and the deformations of the two fragments. The results suggest that the effect of shells at Z=50 and N=82 do not cause large deviation from the liquid drop model charge density around mass 132; their effect is much more pronounced in the fragment excitation energy. The results also suggest that the fragment excitation and kinetic energies for a given mass ratio are markedly by charge density dependent. Some features inherent to this treatment with respect to characteristic period of individual degree of freedom have been discussed.

URANIUM DISTRIBUTION-ROCK

250. THIEL (K) Determination of Uranium distributions in terrestrial and lunar rocks by means of fission track and microprobe technique Kerntechnik 14,11, Nov. 1972, 513-18.

Uranium containing substance is irradiated with thermal neutrons, thus inducing fission of 235U If during the irradiation the investigated substance is in close contact with an appropriate detector foil part of the fission products will penetrate into the detector leaving fission-tracks, which are exposed by an etching technique and counted under a microscope. For quantitative uranium determination an appropriate reference standard is also placed on the detector foil. Uranium concentration is in sample and reference standard are in same ratio as the corresponding fission track densities on the detector. These results yield spatial distribution information.

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b) SUBJECT INDEX

c) AUTHOR INDEX

LIST OF ACRONYMS

Phy	-	Physics
Rev	-	Review
J.	-	Journal
Can.	-	Canadian
Dec	-	December
Aug	-	August
Feb	-	February
Govt	-	Government
Lett	-	Letters
Nucle	-	Nuclear
Trans	-	Translation
Am	-	American
Soc	-	Society
Sept	-	September
Bull	-	Bulletin
Sci	-	Scientific
Tech	-	Technology
Inf	-	Information
Inorg	-	Inorganic
Chem	-	Chemistry
G.B.	-	Great Britain
Nov	-	November
Ins	-	Instruments

Sov	-	Soviet
Jan	-	January
Fiz	-	Fizika
Exp	-	Experimentol
Opt.	-	Optical
Pp	-	Page
Mar	-	March
Ltd	-	Limited
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